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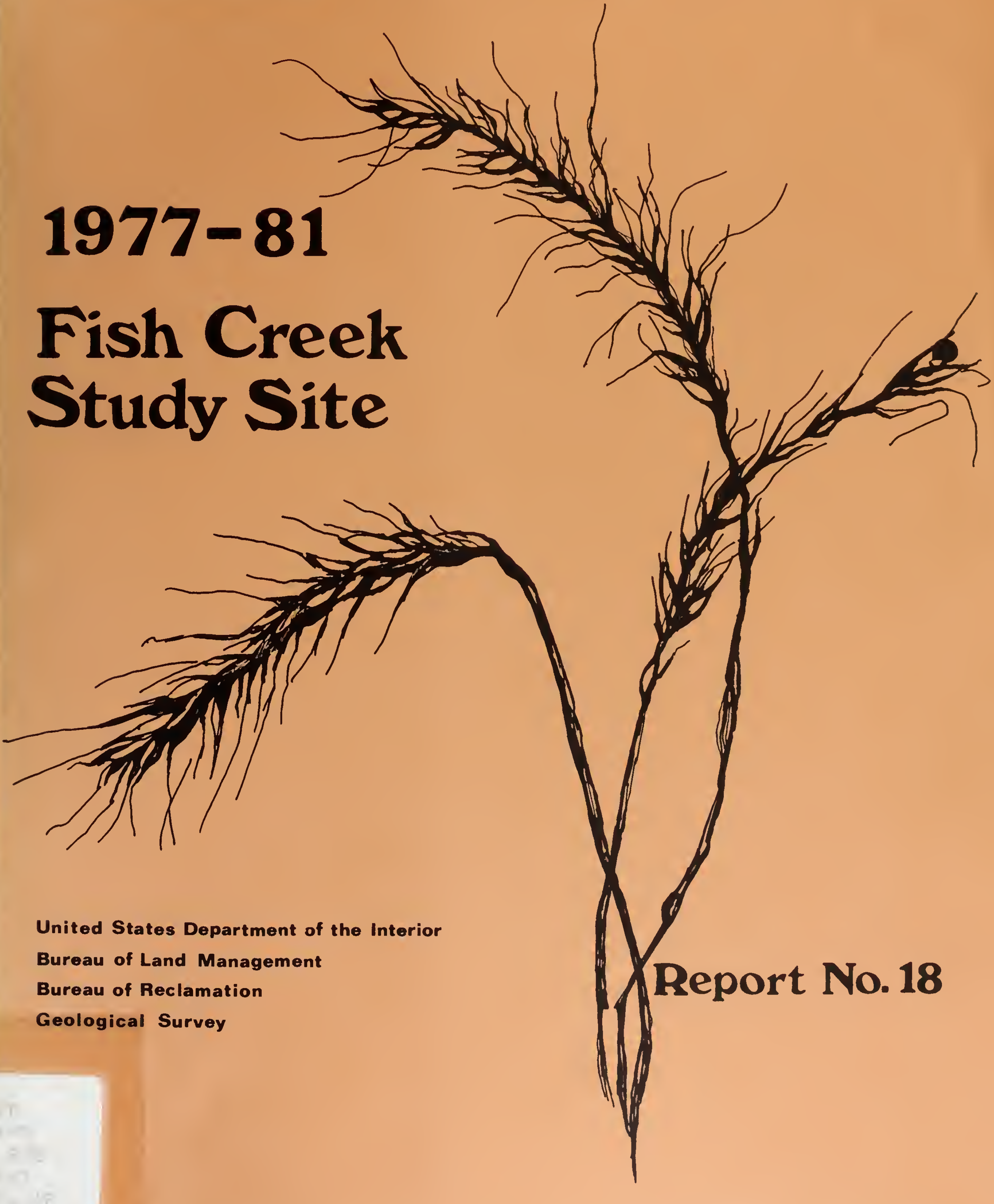

1977-81
Fish Creek Study Site

United States Department of the Interior
Bureau of Land Management
Bureau of Reclamation
Geological Survey

Report No. 18

EMRIA - Energy Mineral Rehabilitation Inventory and Analysis

The purpose of the EMRIA program is to provide information on the reclamation potential of lands under consideration for mineral development or other major land disturbing activities.

The objective of Reclamation Study Area Report is to provide the information needed (in addition to existing information) to enable management officials to determine (1) can the area be effectively reclaimed, (2) what are the major problems involved in reclaiming the site, and (3) what measures would be necessary to establish conditions suitable for the intended post mining use.

These reports are prepared through the efforts of the Department of the Interior pricipally by the Bureau of Land Management, Bureau of Reclamation, and Geological Survey. Assistance is also provided by other Federal and State agencies.

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16. ABSTRACT

The purpose of this investigation was to collect baseline data for establishing reclamation objectives and lease stipulations. The report includes data on climate, biological and cultural resources, physiography, geology, coal resources, soil overburden, vegetation, and hydrology. The study area is within Routt County in Colorado. The site climate is highland continental. Average annual precipitation is less than 16 inches. The area is composed of a sagebrush riparian ecosystem, inhabiting the bottomland and a mountain shrub ecosystem inhabiting the uplands. The Fish Creek coal bed, as much as 5.4 ft thick, is 2 to 20 ft below the top of the Holderness Member of the Upper Cretaceous Williams Fork Formation. Approximately 79 percent of the study area has adequate soil material for postmining reclamation purposes. Approximately 43 percent of the lands in this area have minimum soil depths of 36 inches consisting of highly suitable material for plant media. Less than 4 percent of the bedrock material could be considered for use as a supplemental source for topsoil replacement.

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Fish Creek Study Site Report was prepared through the efforts of the U.S. Department of Interior, principally the Bureau of Land Management, Geological Survey, and Bureau of Reclamation. The study effort began in 1977 and was concluded in 1982 with the publication of this report.

The area described in this report has been tentatively determined to be a potential Federal coal development area. The purpose of this report is to provide information on the area's reclamation potential should coal development occur. This report will assist managers in making final Federal coal leasing decisions.

Editor's Note: In order to more closely associate the EMRIA program with the Federal Coal Management Program, the name "EMRIA" was officially dropped from use in May 1981. The responsibilities of the EMRIA program now come under "Technical Investigations in support of the Federal Coal Management Program."

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INTRODUCTION

The increasing need for energy has focused attention on the energy fuels and sources existing in the western states, primarily the Rocky Mountain and the Northern Great Plains Coal Provinces. Attention to these areas is due to the abundance, simplicity of extraction, and the high quality of the resources present. The Bureau of Land Management is responsible to encourage and assist in meeting these energy demands and at the same time assure sound reclamation so that disturbed lands are returned to a productive and useful state.

PURPOSE

The purpose of this study is to determine the reclamation potential, the problems in reclaiming the area, and the measures required to establish satisfactory conditions.

OBJECTIVES

The objectives of the Federal Coal Management Program are as follows:

1. To evaluate environmental effects of surface mining of areas under consideration for coal development.

2. To provide resource and reclamation information for the leasing site selection procedures set forth by the Secretary of the Interior.

3. To provide environmental resource and reclamation information needed for development of effective lease stipulations as required by the mined land reclamation program.

4. To provide resource, impact, and reclamation information to support state and local regional development and land use planning efforts.

5. To determine the present and potential capability of the surface soil and subsurface resources to support vegetation on known energy fuel deposits.

6. To provide physical and chemical data from which realistic stipulations may be prepared for energy mineral exploration, mining, and reclamation plans.

7. To provide data needed in the preparation of technical examination, environmental analysis records, environmental impact statements, and to aid in the review of mining and reclamation plans for proposed land-disturbing activities in the vicinity of the study.

AUTHORITY

1. Public Land Aministration Act of July 14, 1969 (74 Stat. 506).

2. Federal Land Policy and Management Act of 1976.

3. Surface Mining Control and Reclamation Act of 1977.

RESPONSIBILITY

The following agencies are involved in this program:

Bureau of Land Management

1. Select reclamation study areas for coordinated investigation of vegetation, soil geological structure, surface water, and ground water.

2. Prepare coordination and issue and monitor the execution of work orders.

3. Review and consolidate work order and field office data and prepare input to reports published by the Bureau of Reclamation (Reclamation).

4. Procure easements and rights-of-way to conduct the studies.

5. Distribute technical data, reports, and reclamation and rehabilitation recommendations to field offices.

Bureau of Reclamation

1. Conduct land studies, including a land classification, soil survey, and laboratory characterization program.

2. Conduct drilling operations for the procurement of core samples to be used for the analysis of geological strata in overburden materials.

3. Map surface geology.

4. Prepare geologic logs on drill holes.

5. Collect coal samples.

6. Install casing in holes selected for ground-water observation wells.

7. Characterize and interpret data available on soils and overburden materials, as well as substrata immediately below the coal resources, in relation to reclamation and revegetation.

8. Advise and recommend suitable plant species for use in areas to be reclaimed.

9. Advise and recommend reclamation techniques.

10. Coordinate, assemble, and print final report.

Geological Survey

1. Conduct soil/vegetation and sediment studies which will result in soil/vegetation maps, hydrologic properties of soils, and sediment data.

2. Assess reclamation potential based on water availability.

3. Prepare sediment yield maps.

4. Prepare erodability illustrations.

5. Determine rainfall-runoff relationships and analyze surface and subsurface waters for chemical quality.

6. Evaluate coal sections and prepare well logs.

7. Prepare coalbed maps showing coal resources.

8. Tabulate coal resources estimates.

9. Prepare a table of analytical results on coal resources.

10. Prepare a graphic presentation of the analytical results:

   a. Vertical - Plotted against well logs.

   b. Horizontal - Plan view if significant.

11. Evaluate the effects of mining on the area hydrology and downstream.

LOCATION AND SETTING

The Fish Creek study site is located approximately 21 mi southwest of Steamboat Springs. The lands being studied lie within Routt County and are described below:

T. 5 N., R. 87 W

sec. 20: all except NE1/4 and the NE1/4 of the NW1/4
sec. 21: all
sec. 22: all except E1/2
sec. 27: all except E1/2
sec. 28: all except S1/2
sec. 29: NE1/4

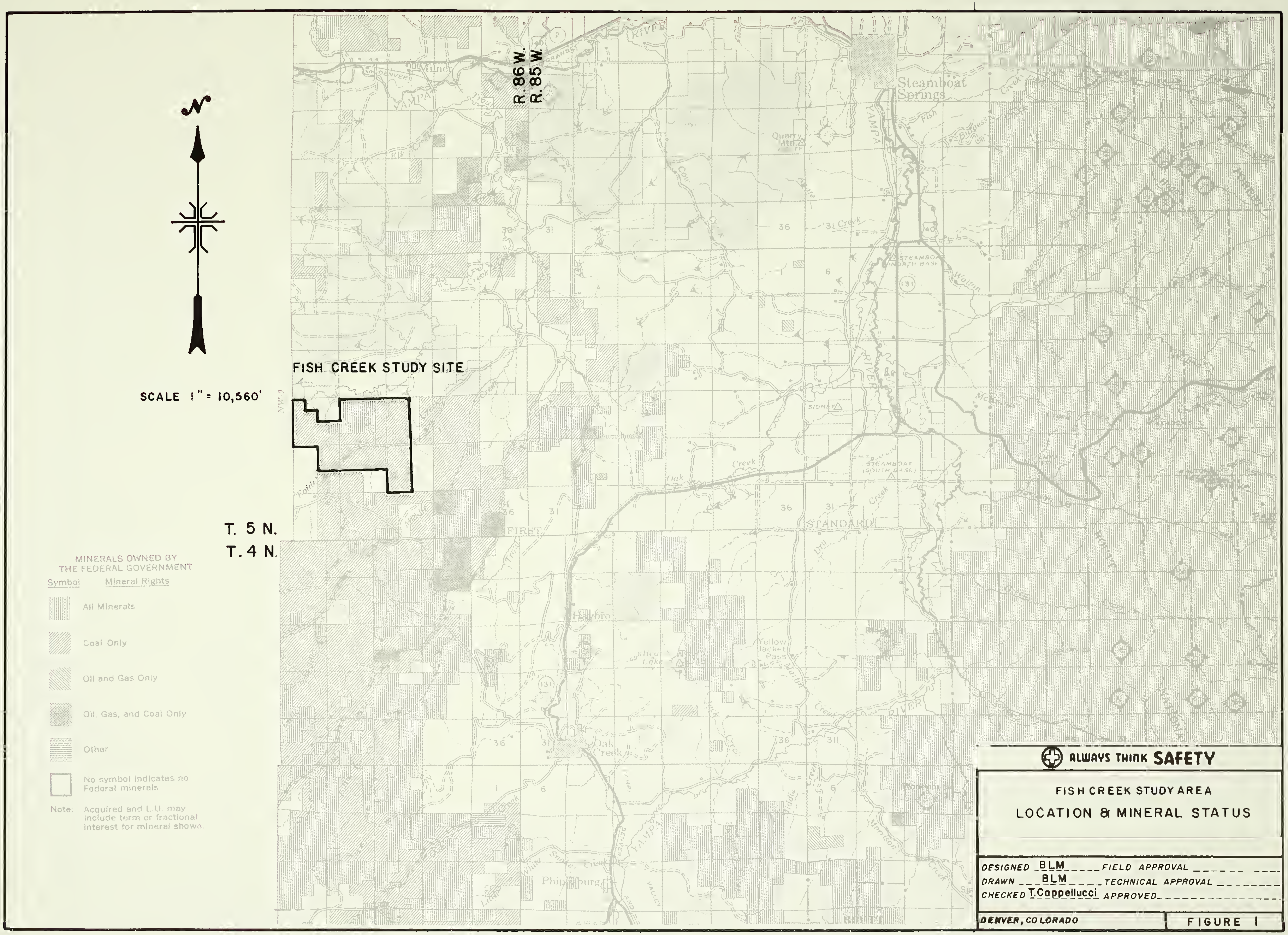


FIGURE 1

FISH CREEK STUDY AREA

LOCATION & MINERAL STATUS

The surface ownership in the study site is private (held mostly by mining companies). The coal minerals are owned by the Federal Government and administered by the Bureau of Land Management.

The communities of Craig, Hayden, and Steamboat Springs are located north along U.S. Highway 40. Colorado State Highway 131 is approximately 3 mi southeast of the study site.

The study site lies at an elevation between 7400 and 6700 ft. Precipitation ranges between 15 and 20 inches. Vegetation consists of short grasses, cultivated cropland, and hayland intermixed.

PRESENT LAND USE

The entire surface area of the study site is privately owned. Approximately 75 percent of the area has been classified as being under cultivation. The remaining land is considered rangeland. One perennial stream, Fish Creek, and one intermittent stream, Foidel Creek, flow through the study site providing riparian habitat.

The cultivated land is used to produce small grain, wheat, and hay for winter livestock feed and improved pasture. The rangeland is used for grazing cattle. Deer and elk use the area for summer and winter range. Small mammals, songbirds, raptors, waterfowl, fur bearers, and upland game birds use the area seasonally.

CLIMATE

The Fish Creek study site is situated in the western Colorado semiarid middle latitude steppes. The site climate is highland continental.

Colorado is in the zone of westerly winds aloft which, depending upon the length of their sojourn over the Pacific Ocean, carry varying amounts of moisture. Thousands of miles from any major sources of moisture, precipitation is generally light in the lower elevations, as large amounts of moisture are drawn off the air masses as they cross major mountain ranges to the west. The air is again cooled as it is lifted over the mountains, giving its available moisture in the form of snow to the west of the Continental Divide during the winter months. During the summer months, this air gives cool temperatures and scattered afternoon thundershowers typical of western Colorado.

The climate is controlled by differences in elevation and by the orientation of the mountain ranges and valleys respecting prevailing air movements.

The rugged topography of western Colorado, and specifically the site, cause large variations in climate within short distances. Average annual precipitation data shows an increase of 7.6 inches from Hayden (elevation 6375 ft) to Steamboat Springs (elevation 6770 ft), which is a distance of only 25 mi with an increase in elevation of 395 ft. Long-term climatic data exists for the Fish Creek study site which lies approximately 12 mi southeast and 19 mi northwest, respectively, from the towns of Hayden, Colorado, and Yampa, Colorado.

Hayden's weather of past years (which constitutes climate) is an adequate guide to conditions in the Fish Creek site during the next decade. Precipitation and temperature values can be expected to run somewhat higher at the site than the values given for Hayden in this report because of orographic lifting and the effect of cold air drainage on Hayden which lies in the Yampa River valley.

TEMPERATURE

Seasonal mean temperatures for Hayden, Colorado, are 57° F for summer (April to September) and 35° F for winter (October to March). Below freezing temperatures in the Hayden area year-round and a chance of greater than 100° F temperatures in the midsummer months of June and July are possible. Similar occurrences can be expected at the study site.

Plant response to temperature is indexed by high and low temperatures that stop growth and an optimum temperature for greatest growth. These cardinal temperatures vary with plant species and developmental stage. Careful selection of revegetation species will need to be done. Daily temperature variations and also diurnal variations may exhibit large ranges that could seriously affect sensitive species during seeding, emergence, transplanting, flowering, and seed dispersal stages.

Late Warm Periods

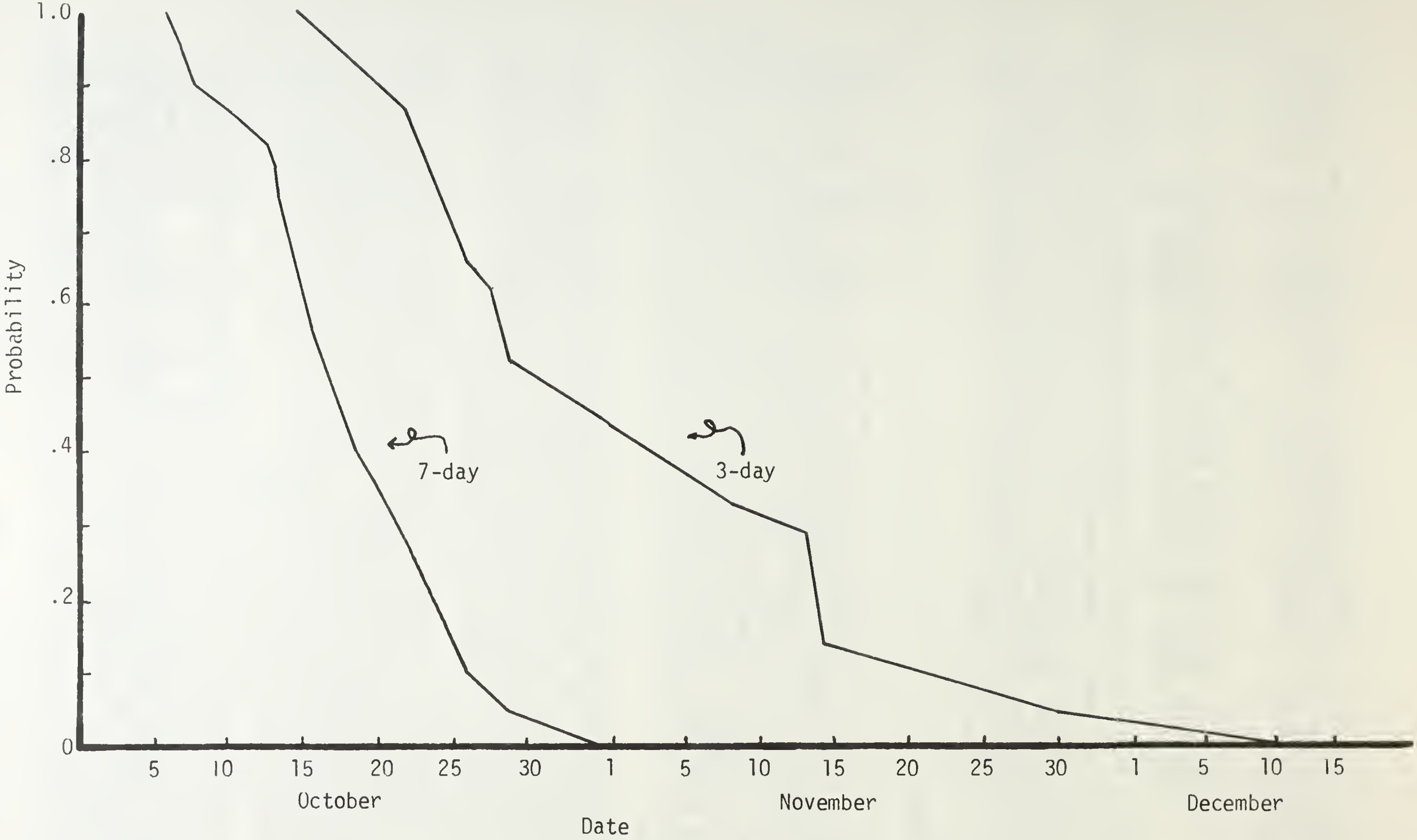
Figure 2 shows the probability of having at least one occurrence of a 3- or 7-day period having a mean temperature greater than 40° F at Hayden after specified dates. Such warm periods can lead to premature germination of fall-planted seed if moisture is available.

An example of the interpretation of this graph is as follows:

Fifty percent of the time there is still at least one occurrence of a 7-day period with a mean temperature greater than 40° F after October 17. For a 3-day period, the equivalent 50 percent date is much later, October 30. There have been occurrences of 3-day periods with a mean temperature greater than 40° F as late as December 10.

GROWING SEASON

The effective growing season at the study site can be approximated by the frost-free period at Hayden, which is from mid-May to mid-September (131 days) and the period of mean daily temperature greater than 32° F, which is from late March to mid-November (235 days). The large range is possible because some plant species are able to resist a drop in temperature below the freezing level for brief periods without damaging their productive growth potential. This drop below the freezing level is a fairly common occurrence during the summer growing season and should be viewed as an important constraint in species selection.



Probability of at least one occurrence of an N-day period with mean temperature > 40°F after given date. Hayden, Colorado, 1948-1975.

FIGURE 2

The ability of certain vegetation species to withstand below-freezing temperatures allows a closer approximation of the growing season. Using a 7-day running mean, temperatures (50 percent probability) at Hayden have stayed for:

182 days above 40° F from April 26 to October 25;
210 days above 35° F from April 11 to November 7;
234 days above 30° F from March 31 to November 20.

The period based on the 40° F threshold temperature is generally considered to be a better approximation of the effective growing season. Active growth for many temperate plants occurs when the average air temperature remains above 40° F. This appears to be a reasonable approximation of the effective growing season at the site, as it falls within the range of the frost-free period and the period of mean daily temperature greater than 32° F.

PRECIPITATION

The Fish Creek study site is in a semiarid region west of the Continental Divide. This region normally receives less than 16 inches of precipitation annually. The precipitation in the region increases from the western part of Colorado to the mountain ranges of the divide as the elevation increases. At four stations in the site region (from west to east respectively), annual precipitation amounts are Maybell, Colorado (elevation 5920 ft), 11 inches; Craig, Colorado (elevation 6440 ft), 13.3 inches; Hayden, Colorado (elevation 6375 ft), 15.6 inches; and Steamboat Springs, Colorado (elevation 6770 ft), 23.2 inches.

Typical of highland-type climates, the controlling factors are elevation and topography. The study site is located in the topographic basin known as Twentymile Park, generally oriented in a north-south direction. The basin is surrounded by mountains from 7,000 to 9,000 ft, which will cause considerable variation of both annual and seasonal precipitation due to the effects on the wind and storm patterns.

The basic mechanisms for producing precipitation on the study site area are (1) large-scale organized storm systems which occur in the winter and spring seasons; (2) orographic lifting which occurs during the same seasons when the prevailing westerly flow aloft is the strongest; and (3) convective thunderstorm activity which is the dominant mechanism during midsummer when large-scale atmospheric circulation is weak, but solar insulation and heating are strong.

Monthly precipitation for Hayden is 7.9 inches during summer (April to October) and 7.7 inches during winter (October to March). Extrapolation of available precipitation data to the study area yields approximately 16 inches of annual precipitation, with a seasonal average of 8.1 inches during the summer and 7.9 inches during the winter. Extreme differences in year-to-year and season-to-season precipitation may cause problems in revegetation efforts. In the 28 years of record (1948 to 1975), the extremes in annual precipitation occurred back to back. For 1957, annual precipitation was 24.6 inches (summer precipitation = 13.2 inches). For 1958, annual precipitation was 11.6 inches (summer precipitation = 5.2 inches). A probability distribution of both annual and seasonal precipitation for Hayden is shown in figure 3. Winter precipitation at Hayden has ranged from 5.1 to 13.8 inches with a mean value of 8.5 inches. Twenty percent of the years, the winter precipitation remains within 1 inches of the mean; 60 percent of the years it remains within 2 inches. Summer precipitation has ranged from 4.3 to 13.2 inches with a mean value of 7.8 inches. Twenty percent of the years summer precipitation remains within 1 inch of the mean; 50 percent of the years, it remains within 2 inches.

It is important to examine the low ends of each distribution as vegetation is limited by the driest years and seasons. Summer precipitation at Hayden of less than 5.2 inches occurs about 1 year in 10. In winter, 1 year in 10 receives less than 5.8 inches of precipitation.

Similar distributions can be expected at the Fish Creek site. Plants chosen for revegetation at the site must be able to tolerate these extreme conditions.

The inconsistency of precipitation may cause severe setbacks to vegetation as the requirements of moisture change with plant developmental stages. For example, plants that germinate in the spring with an ample supply of moisture may face periods in June or July of near drought conditions with little or no rain for weeks that would cripple or kill many plants. If a plant species requires at least 8 inches of summer season precipitation to become established, the local climate will meet these demands only 50 percent of the time.

The frequency and intensity of daily precipitation for a yearly period are shown in figure 4. Individual points on the graph are the probability that a given year will have less than N days with precipitation greater than x, where x is the threshold value of precipitation for each separate line on the graph. The graph shows that for a threshold of 1.0 inch, there is a 54 percent probability that no days will occur with greater than 1.0 inch of precipitation. There is a 50 percent probability that no more than 6 days will occur with greater than 0.5 inches of precipitation evident. The median (50 percent) number of days with precipitation equaling or exceeding 0.2 inch is about 28. In the 28 years of record there has been an average maximum of 1 day per month with precipitation greater than 1 inch for April through December and no events of 1 inch precipitation in January through March. Although potential is high in the summer months for large convective thunderstorms, cloudbursts rarely occur. At no time in the 28 years of record has there been a summer precipitation event greater than 1.3 inches during a single day.

The implications of the graph for successful revegetation are striking. Significant precipitation events are required to substantially contribute to soil moisture content. In dry years daily precipitation totals of 0.5 inch or greater may occur only two times or less. This would place severe moisture stress on young plants. In wetter years six or

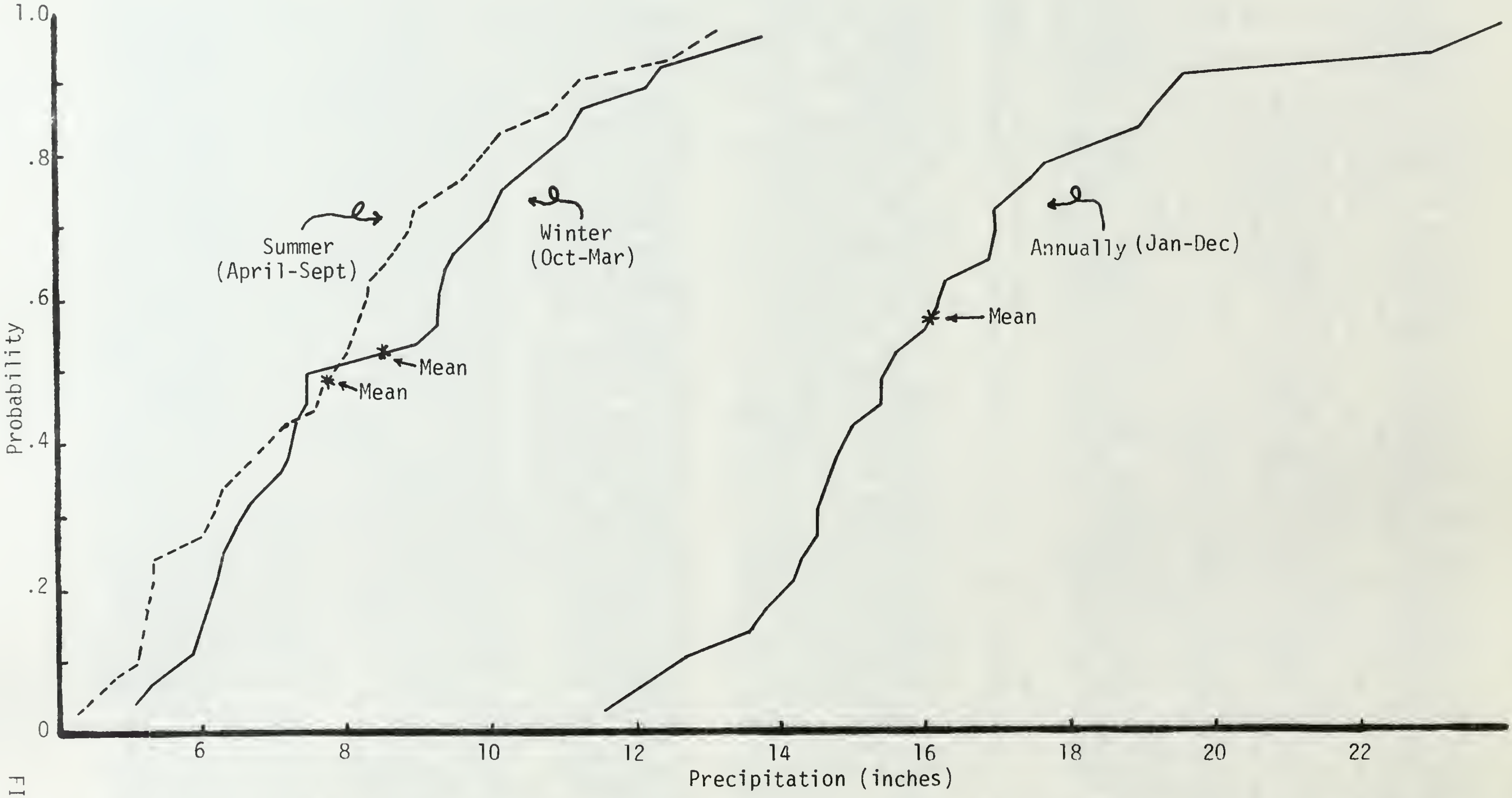
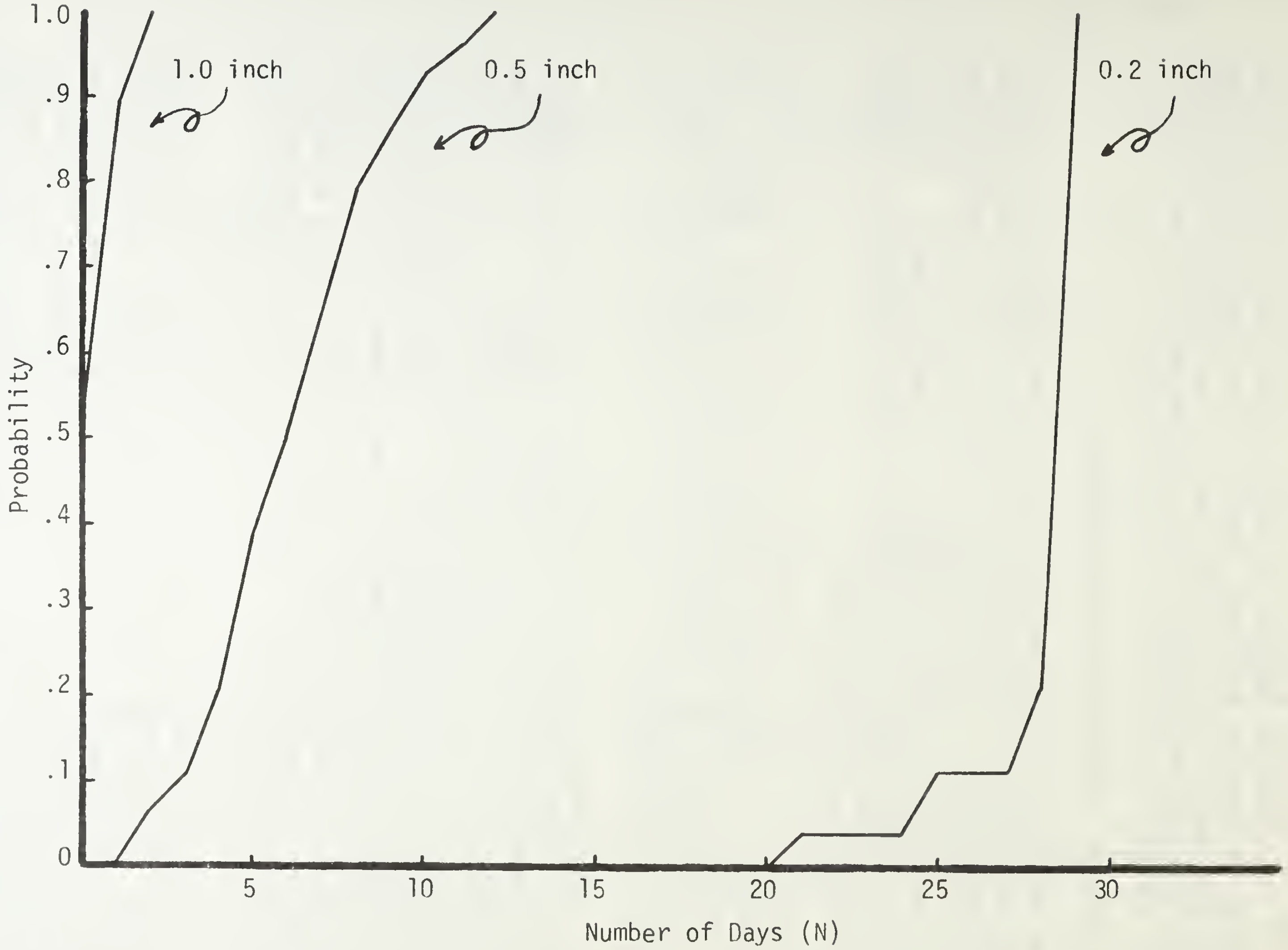


FIGURE 3

Probability of receiving x inches or less of precipitation during winter, summer, and annually at Hayden, Colorado, 1948-1975.



Probability that year has N days or less of precipitation equal to or greater than x inches for Hayden, Colorado, 1948-1975.

FIGURE 4

seven occurrences of precipitation can be expected, thus increasing the probability for establishing successful vegetation.

Annual snowfall is 106 inches, 77 percent of which falls during December, January, February, and March. Snow depth is typically 1 ft or less but can be as great as 3 ft. There is an 83 percent chance of greater than or equal to 1 inch of snow on the ground from November 15 to April 1. This should provide an adequate snow cover for protection of vegetation through the midwinter months. There should be sufficient amounts of snow and wind at the site to apply snow management techniques that would increase the snowpack, delay spring melting, and increase soil water availability into late spring and summer.

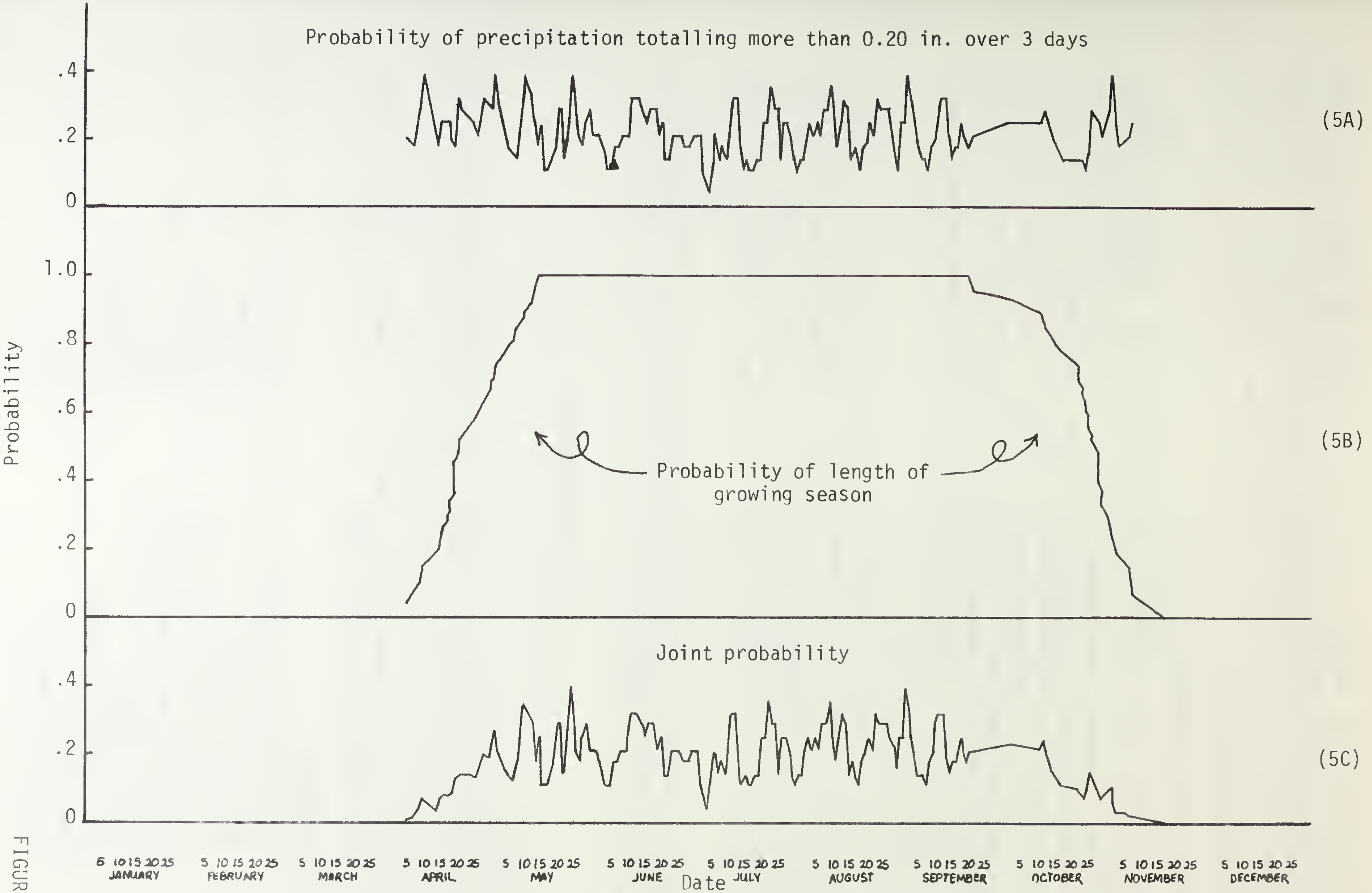
JOINT ANALYSES OF TEMPERATURE AND PRECIPITATION

During the effective growing season, active plant growth will occur if soil water is available. Unfortunately the soil water balance data for most revegetation sites is unavailable. However, rainfall amounts above a reasonable threshold over a period of a few days can be used as a surrogate for the soil water balance of the surface layer. Once the probabilities of the rainfall amount above a given threshold for a given time period are determined, the joint probability of both air temperature and rainfall can be calculated.

For the Hayden data the probability of at least 0.20 inch of rain occurring within a 3-day period was calculated (figure 5(A)). The threshold of 0.20 inch and the 3-day period were used to represent the minimum requirements for growth for newly established plants. Figure 5(B) is the probability of having a 7-day end-element running mean temperature above 40° F.

Figure 5(C) illustrates the joint probability of at least 0.20 inch of rain within a 3-day period and a 7-day end-element running mean air temperature above 40° F (effective growing season). The effective growing season influences the joint temperature rainfall probability for the first 41 days in the spring and the last 59 days in the fall. Between mid-May and mid-September, the rainfall probability alone determines opportunities for active growth. As temperatures warm in the spring, the joint probability gradually rises to above 0.20 in mid-May. The joint probability then decreases to 0.10 the first week in June with an increase to 0.30 during mid-June before decreasing to a minimum of 0.04 in the first week of July. Thereafter, the joint probability erratically fluctuates until air temperature in the fall season again becomes the primary control and the joint probability decreases.

The joint probability analysis has direct implications for plant growth and survival. Although the exact significance of probability thresholds are not known, some periods are clearly better suited for plant growth than others. For example, if one examines the 0.33 joint probability level across the graph, five short periods occur that might be especially favorable for active growth once every 3 years. Considering the 0.10 (1 year in 10) joint probability level, two long periods favorable for active growth can be expected. However, the low probability for



Joint probability (5C) of the mean air temperature being warm enough (40°F) for plant growth (5B) and receiving more than 0.20 inches of precipitation in a 3-day period (5A) for Hayden, Colorado, 1948-1975.

FIGURE 5

rain in early July suggests a lower survival rate for newly established vegetation. This example serves to illustrate the uncertainties of favorable periods for active growth. The probabilities are average and bear no significance for any individual year of interest. The joint probability illustrates the harsh conditions that newly established plants would encounter.

OTHER CLIMATIC ELEMENTS

Data on wind, solar radiation, and evaporation are lacking at stations in the study site area. Therefore, a detailed analysis cannot be supported. However, some general comments can be made. Prevailing wind direction will be locally controlled by the topography of the site with an estimated afternoon windspeed of 8 mph and an evening windspeed of 6 mph. Occasional gusting in winter can occur, resulting in high drifts and windblown bare spots depending on aspect and protection. Wind conditions during the summer and fall are calmer with wind direction more dependent on topography and mountain-valley wind systems. Calm conditions when they occur will be more frequent during evening and early morning hours.

Little is known about the winter solar radiation averages and variations for the site, but for the summer months, cloudiness (therefore solar radiation) is very similar across all of Colorado. On a typical mid-summer day solar radiation total should equal about 60 percent of the extraterrestrial radiation. For June 21 this would equal about 2300 Btu per ft^2/day of solar energy reaching a horizontal surface at the study site.

Maximum evaporation rates occur in midsummer when temperatures are highest. Average annual evapotranspiration at the Fish Creek site is approximately 23 inches.

BIOLOGICAL RESOURCES

WILDLIFE

The Fish Creek study area is composed of a sagebrush riparian ecosystem inhabiting the bottomland with annual cropland and hay land intermixed. A mountain shrub ecosystem inhabits the upland. As a result of the diversity of vegetative types, the area supports a wide variety of wildlife. The following list is comprised of the more common species expected to inhabit the study site:

Possible Mammals

White-tailed jackrabbit
Mountain cottontail
Yellow-bellied marmot
Richardson's ground squirrel
Thirteen-lined ground squirrel
Golden mantled ground squirrel
Least chipmunk
Northern pocket gopher
Deer mouse
Bushy-tailed woodrat
Montane vole
Porcupine
Coyote
Gray fox
Long-tailed weasel
Badger
Striped skunk
Mule deer
Elk
Beaver

Threatened and Endangered Species

Possible presence of endangered whooping crane accompany threatened Greater sandhills crane.

Possible/Probable Birds

Turkey vulture
Cooper's hawk
Red-tailed hawk
Swainson's hawk
Rough-legged hawk
Golden eagle
Marsh hawk
Prairie falcon
American kestrel
Sage grouse
Band-tailed pigeon
Mourning dove
Great-horned owl
Long-eared owl
Poor-will
Common nighthawk
Black-chinned hummingbird
Broad-tailed hummingbird
Common flicker
Hairy woodpecker
Western kingbird
Say's phoebe
Dusky flycatcher
Horned lark
Violet-green swallow
Tree swallow
Rough-winged swallow
Barn swallow
Cliff swallow
Scrub jay
Black-billed magpie
Black-capped chickadee
House wren
American robin
Mountain bluebird
Blue-gray gnatchatcher
Northern shrike
Solitary vireo
Yellow-rumped warbler
Western meadowlark
Red-winged blackbird
Brewer's blackbird
Brown-headed cowbird
Green-tailed towhee
Rufous-sided towhee
Vesper sparrow
Lark sparrow
Dark-eyed junco
Gray-headed junco
Tree sparrow
Chipping sparrow

Deer and elk utilize the area for summer and winter range. Elk use the upper reaches of Foidel Creek, off the study site, for calving.

Small mammal and songbird data are lacking for the study area. The species listed may be expected to be found on the area. Biological factors such as population numbers, density, distribution, and habitat requirements for these species are unknown at this time.

The raptors listed are common users of the ecosystem types found on the study area. In addition, the bald eagle (*Heliaeetus leucoceuphalus*) may be an occasional winter visitor.

Foidel Creek provides the riparian area with the associated use by waterfowl, beaver, and the other associated species. No other data is available for the riparian and aquatic ecosystems.

There are no wild horses using the study site.

Sage grouse and sharptails (Pediocetes phasianellus) use the area. At this time it is not known if any leks are located within the study area.

It is highly probable that nesting habitat would be located adjacent the riparian zone.

There are no data concerning amphibious and reptiles on the study area.

CULTURAL RESOURCES

Two surveys for prehistoric and historic values have been conducted in the area and portions of the surveys are within the Reclamation study site (approximately 165 acres).

The first is a class II survey conducted by the Laboratory of Public Archaeology (LOPA) during summer 1975. It covered approximately 125 acres within the study unit boundaries. The survey is reported in Archaeological Reconnaissance of Proposed Coal Lease Areas in Rio Blanco, Routt and Moffat Counties, Colorado, Christopher Arthur, "Reports of the Laboratory of Public Archaeology No. 1," May 1977. Two prehistoric sites were located and recorded by LOPA on the unit. Site 5RT27 is an open campsite on a gently northward sloping bench. It is within an area that has been under cultivation. No further action necessary on the site is the recommendation given by LOPA. Site 5RT30 is also an open campsite located along both sides of a northwest/southeast trending ridge. The north side of the site is an area that has been under cultivation in the past. The recommendation made by LOPA is that site 5RT30 be nominated to the National Register of Historic Places.

A class III survey also conducted by LOPA in September 1977 covered approximately 40 acres within the study area boundaries. It is reported in Archaeological Reconnaissance of Four Proposed Coal Leases in Routt County, Colorado, Anne P. McNamara, "Reports of the Laboratory of Public Archaeology No. 15," January 1978. No prehistoric or historic sites were located within the unit boundaries.

Powers Elevation, currently under contract with Energy Fuels Corporation, is engaged in a cultural resource survey in the vicinity which includes the eastern section of the study area. No data is available yet from this survey.

PHYSICAL PROFILE

PHYSIOGRAPHY

The Fish Creek study site is located in Routt County, Colorado, approximately 8 miles south of Milner and about 15 miles west of the Park Range. The area is in the southeast end of the Wyoming Basin physiographic province, in a southeast trending prong known as the Washakie-Sand Wash Basin. The prong is a broad syncline which narrows to a point in the southeast. The Yampa coal field occupies the southern end of the point occupying the area from the Elkhead Mountains to near the town of Yampa. A basin in the southern part of the Yampa coal field, known as Twentymile Park, includes the study site. This basin is one of many subsidiary structures within the Yampa coal field portion of the syncline.

General Land Form Features

The dominant feature of the topography of this southern portion of the Yampa coal field is cuesta or hogback ridges with gentle dip slopes and sandstone cliffs on their back sides. The distinction between a cuesta and a hogback is defined by the dip of the beds. If dip is 10° or less, the term cuesta is used. In the study site, although dips may exceed 10°, the term cuesta is used as being more generally applicable to Yampa coal field features. The ridges have been formed where erosion has exposed resistant beds on the flanks of the subsidiary folds. Relief from these ridges may be as much as 1,000 ft.

Land Form of Fish Creek Study Site

The study site lies on the southern edge of the cuesta-rimmed basin of Twentymile Park. The cuesta outcrop trends generally east-west along the south edge of the site except in the southcentral portion of the site where it is divided and trends northwards. North and east of the outcrop and throughout the center of the basin is a rolling prairie surface. The surface is being dissected by eastward flowing intermittent streams.

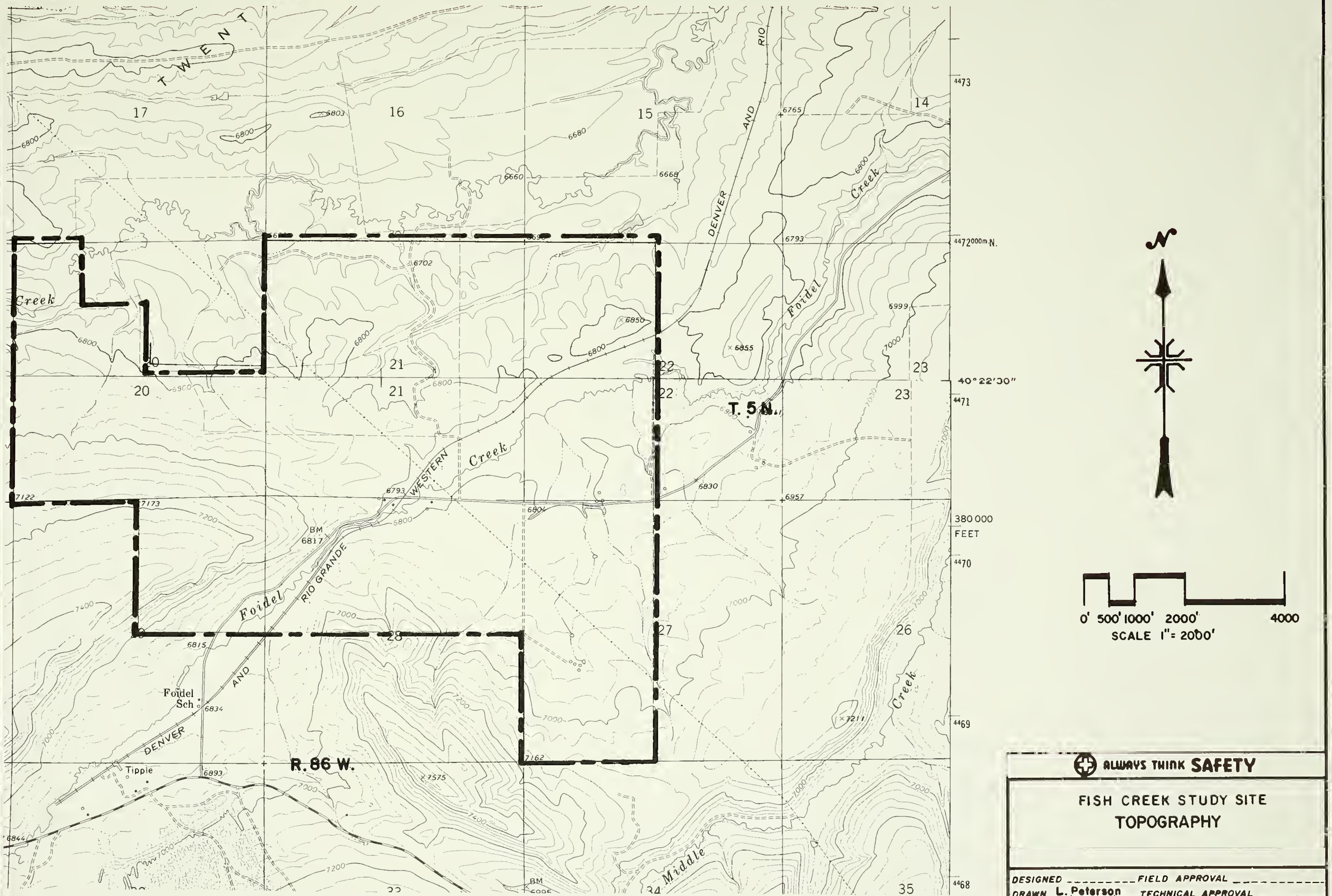
Elevation and Relief

The highest point in the study site is the ridge rim at the southwest corner having an elevation of 7400 ft. The lowest point (6720 ft) is northeastward along Fish Creek, giving maximum relief of 680 ft. Within the basin, elevations range from about 6800 ft on the west to 6600 ft on the east, between the points where the dip slopes of the cuestas begin their ridge forming rises. Interstream divides between intermittent drainages which cross the basin reach maximum relief of 100 ft. The study site includes parts of both the dip slopes and the basin surface. The grade of the dip slope surface ranges from 10 to 30 percent while the grade of the slope of the basin surface is only 1 to 2 percent.

Elevations of drill holes may be found on the geologic logs. Data provided is only approximate, having been taken from 7.5 minute quadrangle maps with 40-ft contour intervals.

Drainage

Two perennial streams drain the study area: Fish Creek, which flows along the north edge of the area; and Foidel Creek, which flows northeast through the center of the area. Several tributary intermittent



BASE MAP SOURCE: U.S.G.S. 7 1/2' QUADS–RATTLESNAKE BUTTE, COLO., MILNER, COLO.
CONTOUR INTERVAL: 40 feet

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FISH CREEK STUDY SITE
TOPOGRAPHY

DESIGNED ________ FIELD APPROVAL ________
DRAWN L. Peterson TECHNICAL APPROVAL ________
CHECKED T.Cappellucci APPROVED ________

DENVER, COLORADO

FIGURE 6

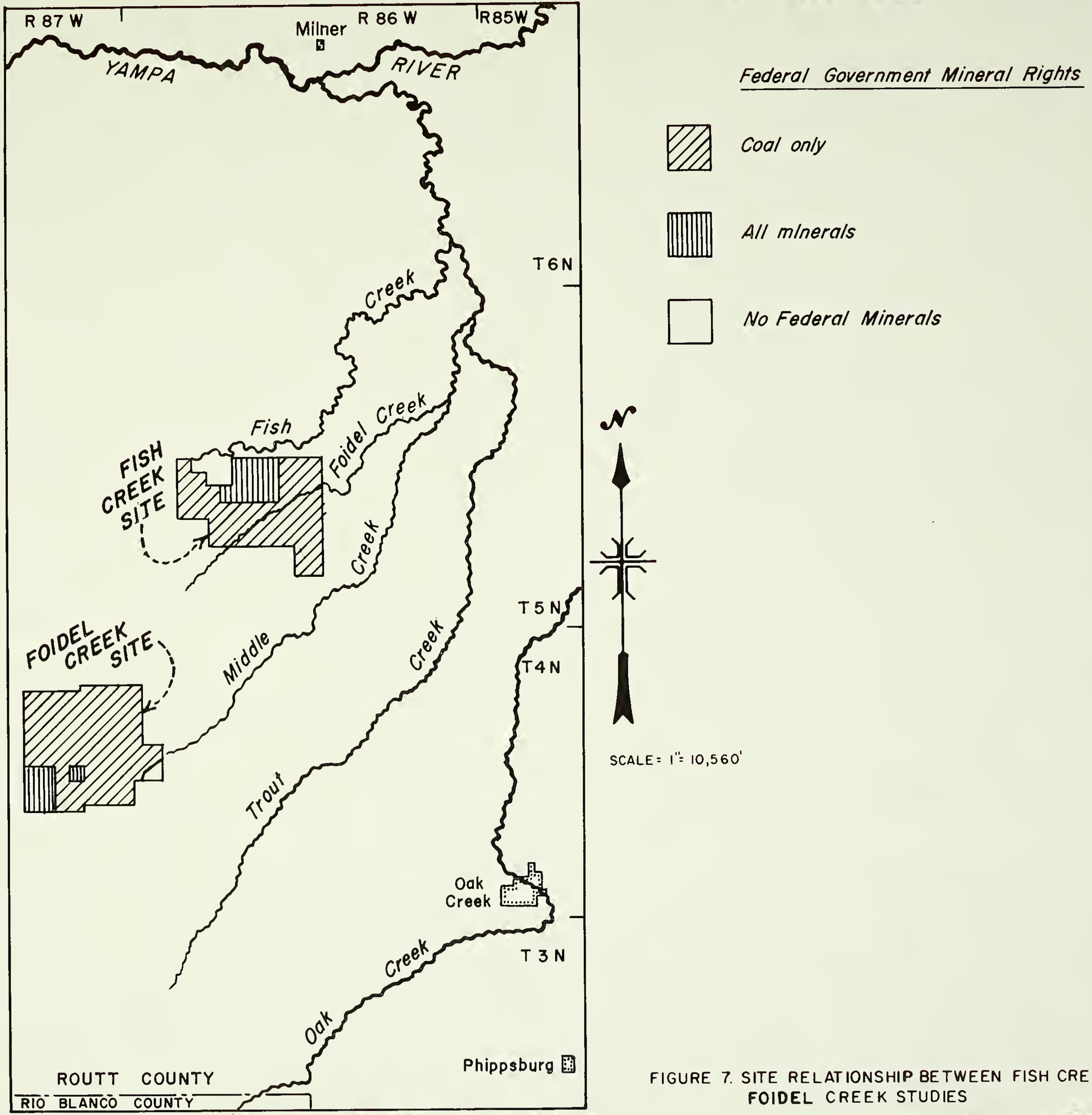


FIGURE 7. SITE RELATIONSHIP BETWEEN FISH CREEK AND FOIDEL CREEK STUDIES

streams drain northwards into these two streams. Drainage pattern of the tributaries is primarily dendritic.

Fish Creek flows into Trout Creek about 3 mi northeast of the study site. Foidel Creek is a tributary to Middle Creek which flows into Trout Creek. Trout Creek is a north-flowing tributary of the Yampa River, a major river in the Upper Colorado River drainage system. The Yampa is about 6 mi north of the study site and flows westward across Colorado to the Uinta Mountains of Utah.

Fish Creek and Foidel Creek both head outside the Twentymile Basin. Fish Creek enters the basin at its southwest edge where the basin-rimming ridges swing apart to form a gap. Within the basin, Fish Creek flows east-west until it encounters the west rim of the basin where it swings northward. The basin segment of Fish Creek exhibits an extensively developed meander pattern, a result of its low gradient, small size, and sediment easily eroded from the clay surface of the basin.

North of Fish Creek, drainage of the basin is accomplished by the succession of parallel eastward flowing intermittent streams which drain into Fish Creek after it trends northward.

Foidel Creek enters the study site from the south and flows along the base of the outward facing sandstone cliff of the cuesta ridge, until it enters the basin where it has breached the ridge at the apex of the northward bulge in the outcrop. Once in the basin, Foidel Creek flows parallel to the basin rim along a dissected bench which merges into the northfacing dip slope. Its elevation is about 100 ft above Fish Creek. Between them is the interstream divide which rises about 40 ft above Foidel Creek. The slope from this divide down to Fish Creek is dissected by intermittent streams. Where Foidel Creek flows within the basin in the southeastern portion of the study site, an intermittent channel trends east-west across the slope north of Foidel Creek more than a mile before it bends northwards to flow into Fish Creek. This drainage creates another minor ridge north of the interstream divide ridge. Both ridges have a dissected profile. The southward facing slopes of these ridges are moderately steep as compared to the gentle slopes in the remainder of the basin system. In the western portion of the study site, where Foidel Creek is without the basin, intermittent tributaries simply drain northwards down the dip slope and across the basin surface to Fish Creek.

Figure 6 shows the topography of the Fish Creek study area.

GEOLOGY

Regional Geology

The Fish Creek site lies north of the Foidel Creek site in Routt County in Colorado. Figure 7 shows the relationship of the two study sites. The outcropping formations which include coal beds in the general area are the Iles and Williams Fork Formations, which comprise the Mesa Verde Group. The Fish Creek coal bed in the upper portion of the

Williams Fork Formation is the coal bed of interest for this study site because it is the only coal which may occur at levels feasible for surface mining. Two regional geologic features are of primary significance when considering the surface mining of the Fish Creek coal. The first determines the characteristics of the coal-bearing and overburden units, and the second controls their location.

First, the character and extent of the Fish Creek coal-bearing sedimentary sequence and the sediments overlying it in the study site reflect depositional environment on the fluctuating eastern shoreline of an Upper Cretaceous Sea. Lateral variability, transitional zones between terrestrial and marine sediments, and the absence of some horizons where embayments in the shoreline occurred, can all be expected. The relationship between the overburden and the coal, both vertically and laterally, will therefore be variable. Nevertheless, it must be defined for the study site in order to evaluate extent and nature of overburden present. This problem is discussed further under stratigraphy.

Second, the geologic structure of the area controls the presence of the coal seams and their exposure near the surface. In the Rocky Mountain area, Cretaceous sediments have been removed by erosion except in isolated structural basins. The Yampa coal field lies in the Washakie-Sandwash Basin. Coal seams, including the Fish Creek coal, are present in the preserved Cretaceous sediments.

The basin contains subsidiary folds, including the Twentymile syncline. The Twentymile syncline trends northwest from the vicinity of Phippsburg to near Milner. Erosion of the flanks of the syncline has exposed coal-bearing sedimentary beds at or near the surface. The configuration of the synclinal flanks determines the depth and direction of the coal seams.

The Fish Creek site is in the Twentymile Park area of the Twentymile syncline. Here the synclinal flanks flare out to form a bowl-shaped basin 3 to 4 mi wide and 8 mi long. Around the margins of the bowl the resistant Twentymile and Trout Creek sandstones rise to the surface forming outward facing cliffs. The basin lies in the northern portion of the syncline, which plunges northwards. Successively older sedimentary units are therefore exposed southwards. The Fish Creek coal bed occurs north of the Twentymile sandstone.

Rocks that form the northwest side of the Twentymile Park Basin dip into it as a much steeper angle than the gently dipping beds on the southeast side. Thus the southeast side of the basin offers the best likelihood of a wide band of coal occurring at shallow depths.

Site Geology

Units present. Rock units outcropping in the Fish Creek site are the Williams Fork and Lewis Formations. The Twentymile sandstone member of the Williams Fork Formation forms the cuesta ridge along the south edge of the site. Underlying the outward facing cliff formed by the Twentymile sandstone, on the north side of Foidel Creek, the marine shale member is present under some surficial cover. The inner dip slopes are in the Holderness member which overlies the Twentymile sandstone. These slopes are dissected and merge with the Lewis Shale which underlies the central surface of the basin. A geologic map of the Fish Creek site showing location of these units may be found in plate 1.

Local structure. The Twentymile sandstone outcrop defines the trend of the basin flank in the Fish Creek site. Configuration of the basin has been generally defined by Bass (1955). Figure 8 shows the general outline of the basin within the Twentymile syncline and the location of the study site and geologic cross sections.

Beds dip more steeply into the basin on the northwest flank than on the eastern and southern sides. In the Fish Creek site, dips quickly become fairly gentle as one moves down from the cuesta rim towards the basin center. The 18-degree dip recorded in the sandstone at the basin rim (see plate 1) is maximum for the study site, but not typical, even on the rims. In the drill hole area, dips appear to be 4 to 5 degrees. Cross section C-C' (plate 2) illustrates the flattening of dips towards the basin center.

Stratigraphy and Geologic Logs

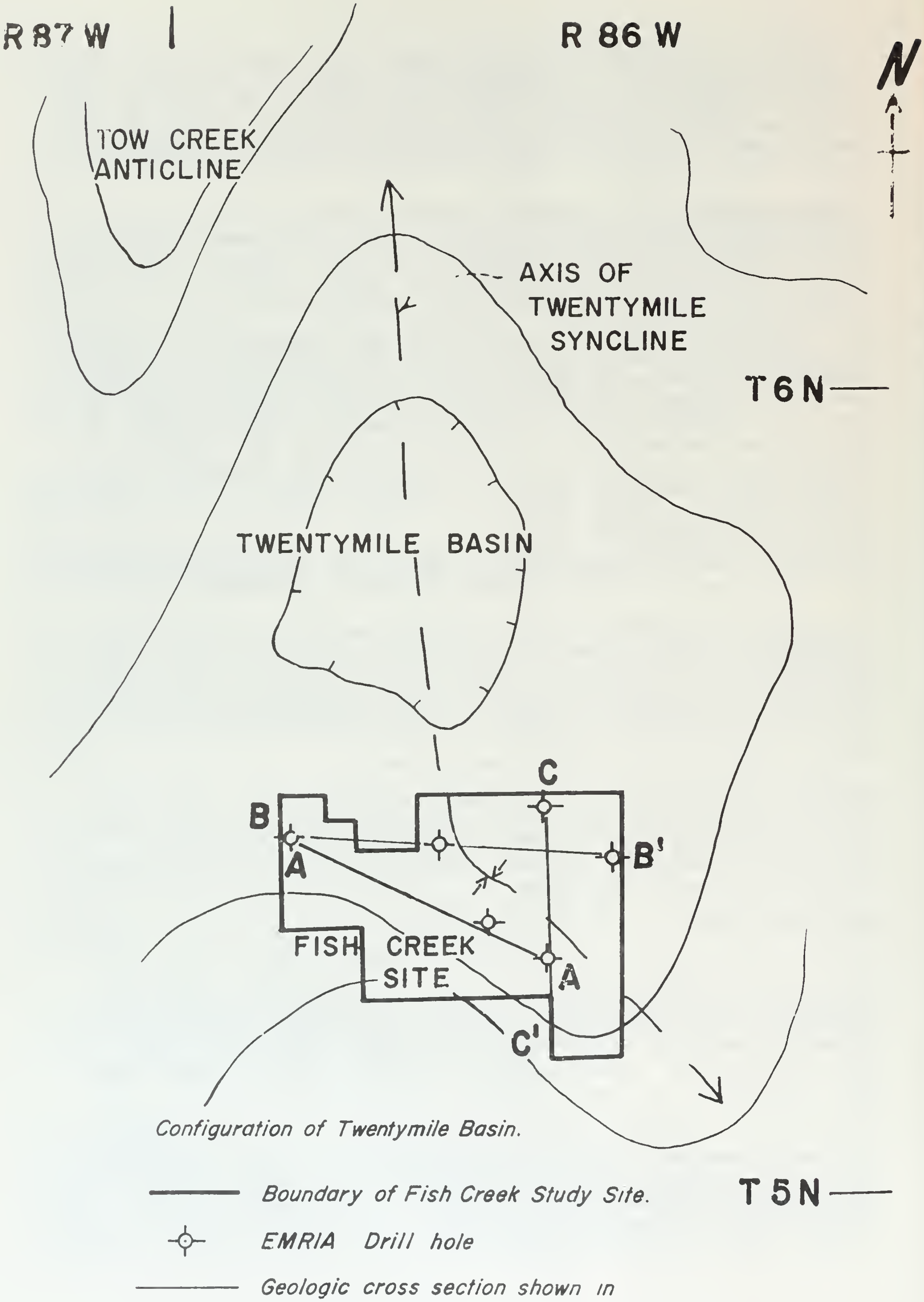
Stratigraphic units exposed in the study site are the Upper Cretaceous age Lewis Shale and Williams Fork Formation and recent stream alluvium.

The geologic map (plate 1) of the study site shows contacts between these units. Contacts between the Cretaceous units are transitional and not well exposed, and have been taken from published maps (Bass, 1955, Ryer, 1976) and adapted slightly to reflect information obtained from drill holes. Boundaries of stream alluvium are based on interpretation of aerial photos. Where contacts are transitional or otherwise not well defined, they are so indicated by dotted lines.

The following description of stratigraphic units include a description of the stratigraphic group to which the study site units belong as well as a more detailed description of units encountered in drill holes. A stratigraphic column of the area is shown in figure 9. The geologic logs are contained in appendix A.

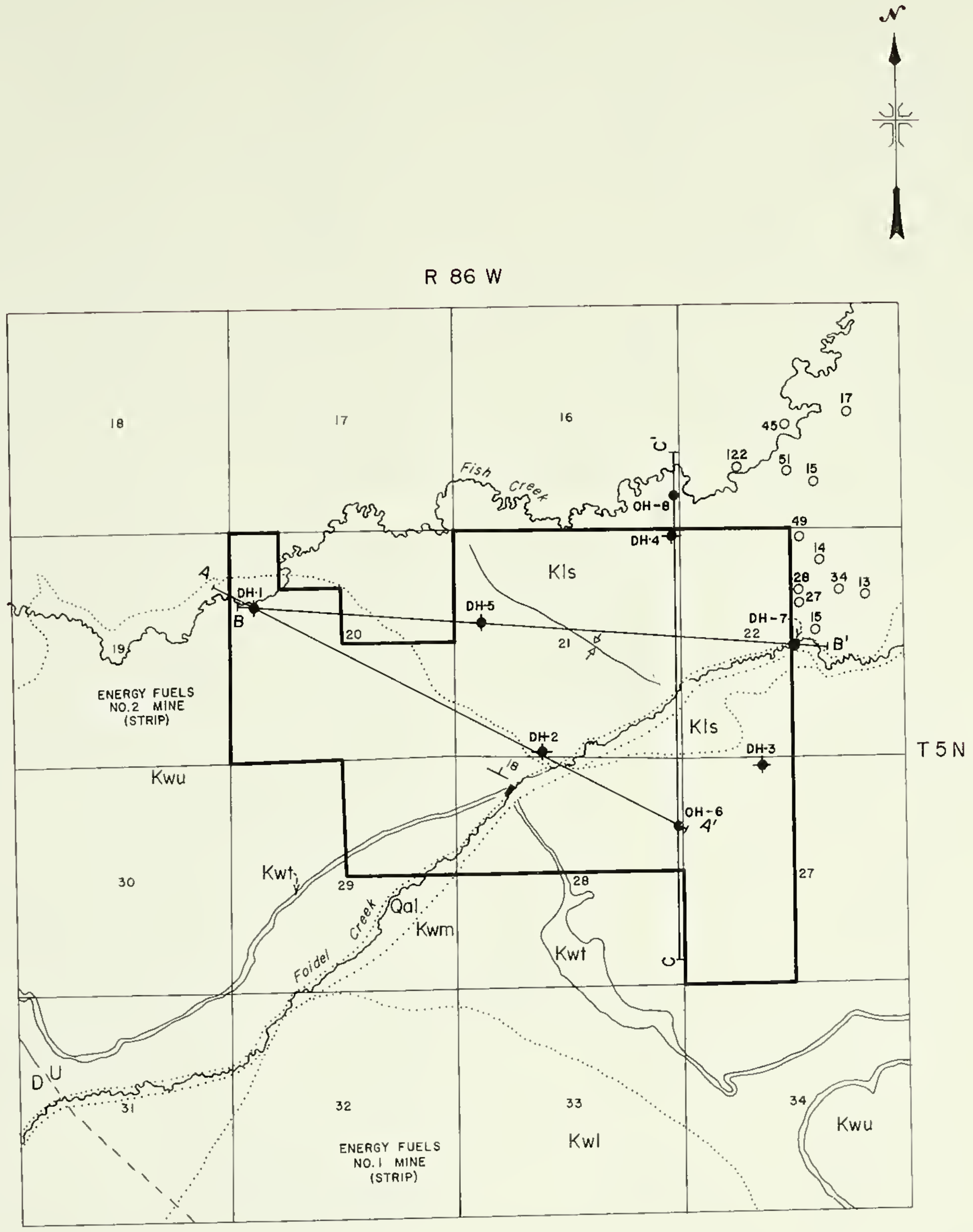
Mesa Verde Group

The Mesa Verde Group includes the lower, middle, and upper coal-bearing units mined in the Yampa coal field. It consists of sequences of sandstone, siltstone, shale, limestone, and coal beds representing deposition along a varying strand line of the Upper Cretaceous sea. Contacts between many of the beds are gradational. Some fairly persistent sandstone beds in the sequence serve as markers to separate the Mesa Verde Group into two formations, the Iles and overlying it, the Williams Fork. The base of the group is marked by the Tow Creek sandstone; the Trout Creek sandstone marks the top of the Iles Formation. The Iles Formation is approximately 1,400 ft thick and contains the lower coal group. It outcrops south of the study site. The Williams Fork Formation overlying the Iles is about 1,200 ft thick. It contains the middle and upper coal groups.



Configuration of Twentymile Basin.

FIGURE 8. CONFIGURATION OF TWENTYMILE BASIN



EXPLANATION

Qal	*Alluvium*	*Clay, sand, gravel*
Kls	*Lewis Formation*	*Mudstone, dark gray to black. Calcareous in most places, carbonaceous. Interbedded in places with limestone laminae and minor limestone beds which may show turbulent and slump bedding. Fossiliferous in places.* *—Transitional contact —*
Kwu Kwt Kwm Kwl	*Williams Fork Formation*	*Kwu, Upper member (Holderness Member). Sandstone; interbedded sandstone and mudstone; limestone; silty shale; coal. Fish Creek coal bed, 1–5' thick in upper 10'. Sandstone and mudstone interbedded in sequences showing turbulent and stump bedding and infillings. Calcareous, carbonaceous, fossiliferous in places.* *Kwt, Twentymile Sandstone Member, Sandstone, gray, massive. Cross-bedded in Cliff-forming; weathers to buff. Can be artesian aquifier. Carbonaceous.* *Kwm, Marine Shale Member.* *Kwl, Lower Member, Sandstone, silty sandstone, siltstone, shale, coal beds. Wolf Creek and Wadge coal beds in lower part.*

━━	*Boundary EMRIA - Fish Creek study site.*
—·····	*Boundary lithologic units. Dotted where transitional or uncertain.*
▬	*Outcrop of coal bed.*
	Trend of axis of Twentymile Park syncline
U D - - -	*Fault, dashed where uncertain.*
6°	*Strike and dip of beds*
DH-1	*Location of project drill hole.*
OH-6 ●	*Location of known drill hole used in cross-section*
15 ○	*Location of known drill hole; depth to coal.*
A—A'	*Line of cross-section. See drawing no. geologic cross sections A-A', B-B', C-C'.*

NOTE: Geology based on "Geology and Mineral Fuels of Parts of Routt and Moffat Counties, Colorado," U.S.G.S. Bull. 1027–D, by N. Wood Bass, J. Brian Eby, and Marius R. Campbell, 1955; Ryer Thomas, EMRIA Report No. 6, 1976;

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

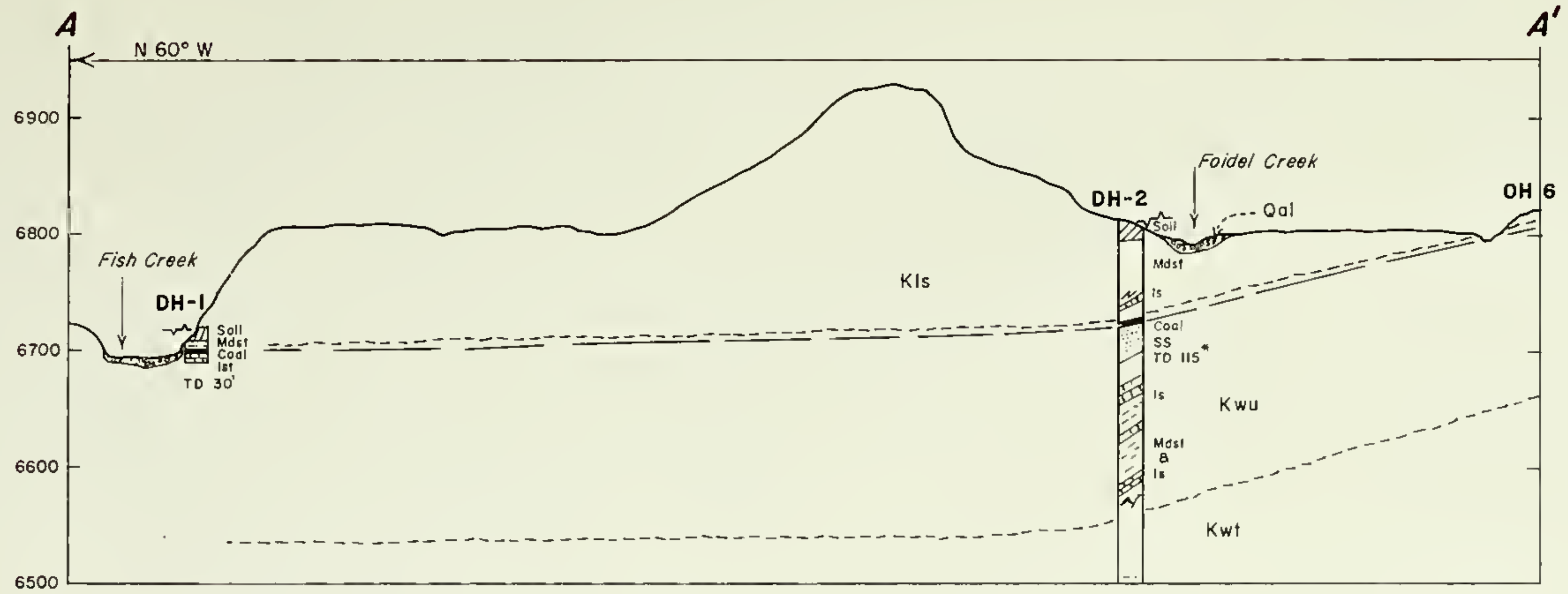
ENERGY MINERAL REHABILITATION
INVENTORY AND ANALYSES

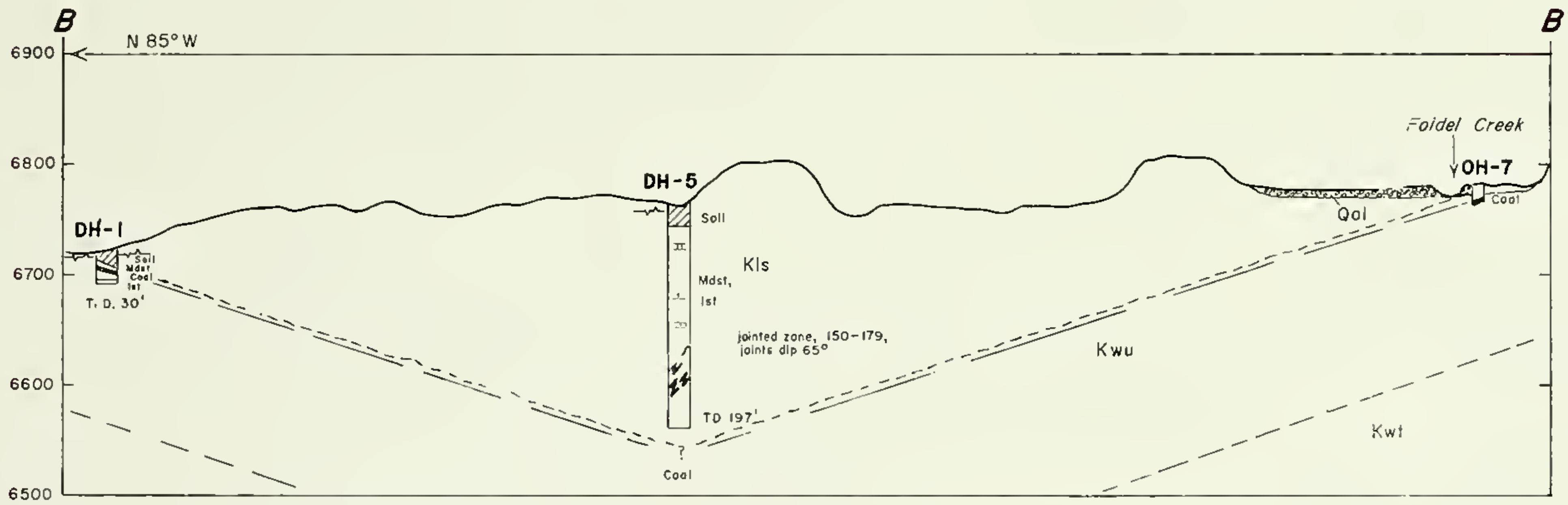
FISH CREEK SITE

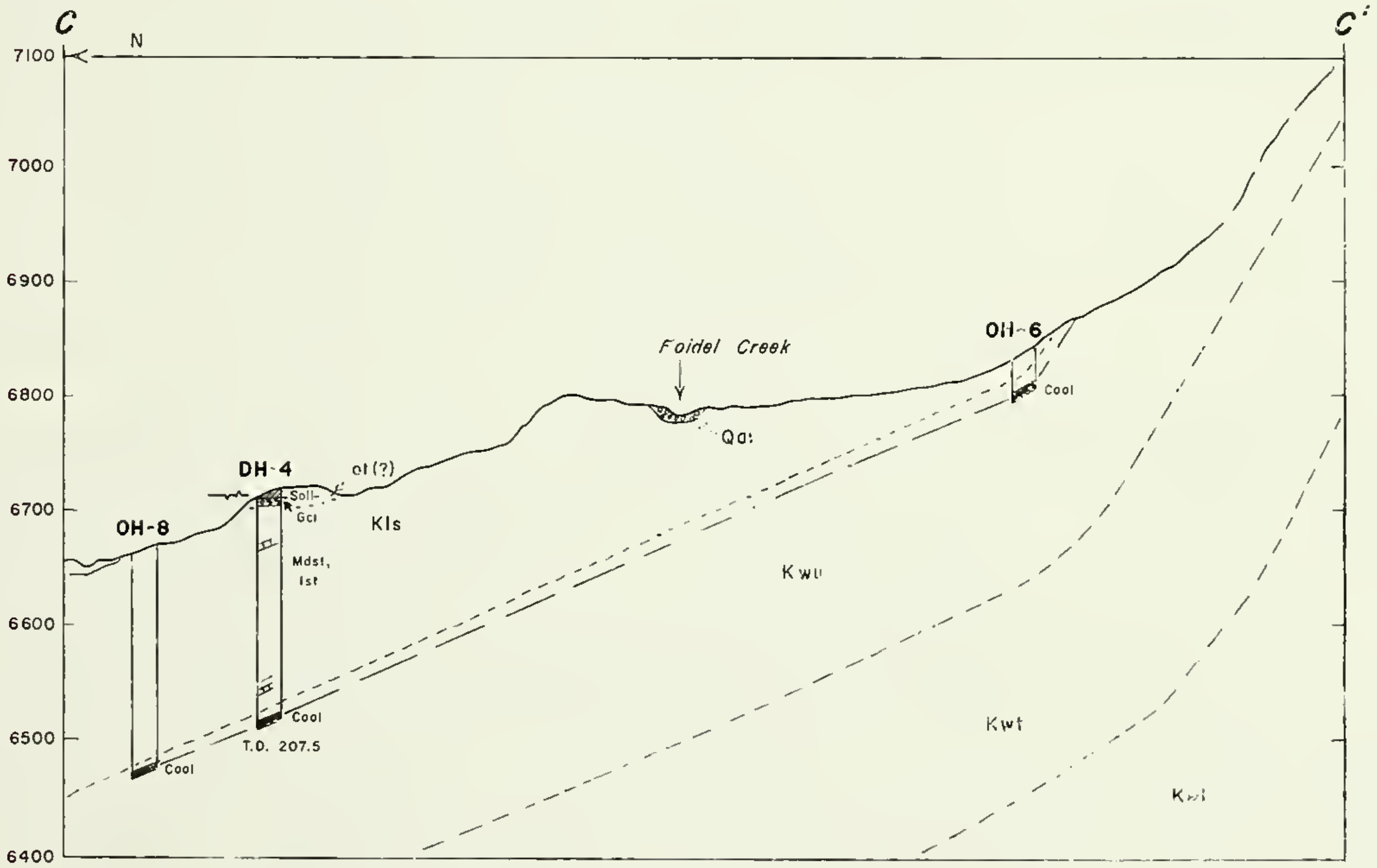
GEOLOGIC MAP

GEOLOGY Ryer Bass SUBMITTED
DRAWN W.F. RECOMMENDED Jane Tomkin
CHECKED J.T. APPROVED

DENVER, COLORADO OCT. 7, 1976 PLATE I







EXPLANATION

	Surficial Soil Deposits
Soil	Clay Highly plastic, contains $CaCo_3$ or gypsum, Fe stains
Qal	*Stream alluvium*
	Terrace alluvium (?) Qt
Gcl	Clay, gravel. Clay, highly plastic. Gravel, subrounded fragments 1" maximum, layer 2' thick.
	Lewis Formation Kls
Mdst	Mudstone Dark grey to black. Usually calcareous and carbonaceous. Cohesive except where jointed and brecciated. May be fossiliferous. Partings range from smooth to neatly conchoidal. Massive, little indication of bedding
Lst	Limestone. Occurs in nodules, laminae and scattered thin beds in mudstone. Gray, dense, with conchoidal partings. May be carbonaceous, fossiliferous
	Holderness Member, Williams Fork Formation Kwu
SS	Sandstone. Fine-grained, Gray-light buff Often underlies Fish Creek coal bed. Contains quartz and chert grains, white clay cementation.
COAL	Primarily shiny black; some dull bands Very minor pyrite
	Twentymile Sandstone Member, Williams Fork Formation Kwt
SS	Sandstone. May vary from fine to medium grained Gray, weathers to buff Carbonaceous

▬ —— ——— Fish Creek coal bed and estimated line of extension

- - - - - - Transitional contact between lithologic units

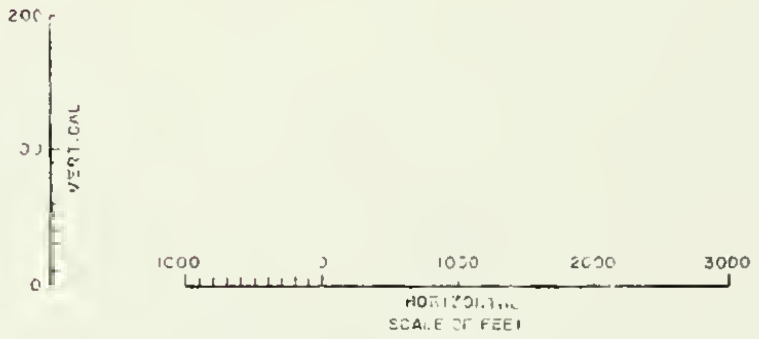
Jointed and brecciated zone

Water level

T. O. Total depth

Graphic log of drill hole

*DH-2 Description below 115' from additional depth drilled by Geologic Survey



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INVENTORY AND ANALYSES

FISH CREEK SITE
GEOLOGIC CROSS SECTIONS

GEOLOGY J.T. SUBMITTED
DRAWN W. F. RECOMMENDED
CHECKED J.T APPROVED

DENVER, COLORADO OCT. 7, 1976 PLATE 2

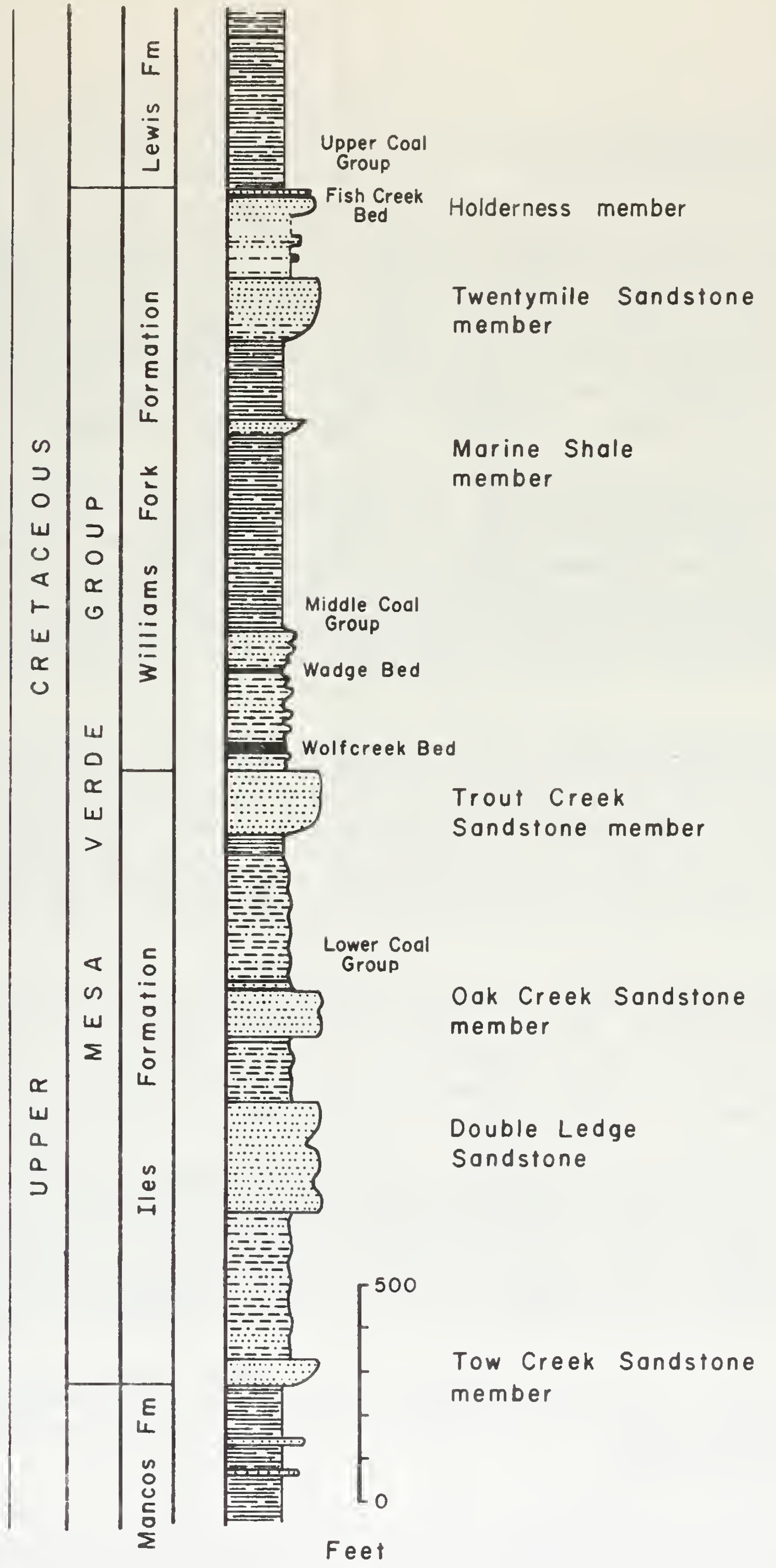


Figure 9. Generalized stratigraphic section of strata exposed in the mapped area. (from Thomas A. Ryer, U.S.G.S., 1976)

Units in Williams Fork Formation

The lower unit in the Williams Fork is predominately a medium gray siltstone, with numerous horizons of sandstone, silty sandstone, shale, and the coal beds of the middle coal group. The Wolf Creek and Wadge coal beds are the thickest and most persistent beds in the middle group. The Wadge bed has been mined south of the study area by Energy Fuels Corporation where a dip slope formed on resistant beds in the upper part of the lower unit forms the south side of the valley of Foidel Creek. This lower unit does not crop out in the study area.

Overlying the lower unit is a thick unit of marine shale, estimated to be slightly less than 700 ft thick. It underlies much of the northern slope of the Foidel Creek valley. The marine shale unit becomes increasingly silty and includes sandstone beds as it grades upward into the cliff-forming Twentymile sandstone unit. This sandstone is a marine sandstone, carbonaceous in places. Outcrop thickness is about 120 ft. It forms the rim of the Twentymile basin, and can be an artesian aquifer downslope.

The Twentymile sandstone grades into the upper member of the Williams Fork. The upper member has been called the Holderness member by Masters (1966), who describes it as an easterly thinning wedge of lagoonal and beach rocks which intertongue with overlying and underlying sediments. Its thickness in the study site is about 190 ft. Ryer described it primarily as light gray to tan, silty, very fine laminated sandstone interbedded with medium to dark gray homogeneous to laminated siltstones.

Exposures are generally poor. The Fish Creek coal bed is in the upper portion of the Holderness member, probably within the upper 15 ft. It occurs in an interval usually covered in outcrop. One road cut exposure is present in the site. Above the coal, the Holderness grades into the Lewis Shale.

Because the Lewis Shale overlying the coal and the Holderness Formation underlying it are variable laterally, have transitional contacts, and are poorly exposed, one goal of the drilling program was to accumulate data defining characteristics of each which would distinguish one from the other. Further, it was hoped a marker horizon related to the coal could be identified, which would help predict its presence and depth.

The following description of the Holderness member, most of which underlies the coal, is therefore included as pertinent to the overburden study. It is based primarily on the core from DH-2 which was taken down to the Twentymile sandstone.

A gray, fine-grained sandstone with salt- and pepper-like grains, about 177 ft below the coal, was taken at the top of the Twentymile sandstone. This grades upwards into a 60-ft sequence which is primarily dark gray mudstone. For the next 60 ft, the mudstone is increasingly interbedded with light gray sandy limestone and calcareous sandstone and siltstone.

In this interval, the mudstone and siltstone are dark gray and constitute contorted infillings. These were interpreted by Ryer (1976) as cavities produced by plant roots. Laminar surfaces may be quite carbonaceous. Above this contorted sequence is about 50 ft of gray salt and pepper sandstone, almost unconsolidated in places, which becomes increasingly calcareous with depth and shows concentrations of carbonaceous fragments on bedding plane laminae. The coal interval occurs above this sandstone. In two holes, a 2.4- to 3-ft thick buff fine-grained sandstone with chert grains is present above the sandstone and just underlying the coal. Ryer described a 6-ft thick sandstone with similar characteristics in this position. In DH-1, a limestone is present in this position instead. Thickness of the coal in the study site varies from 1.3 ft in DH-1, above the limestone, to 5.9 ft in DH-2, where it overlies sandstone. Energy Fuels Corporation is mining from a 4- to 6-ft thickness of the Fish Creek coal just west of the study site. The variability of thickness of coal and underlying sediment type is to be expected. A pattern of coal thicknesses from private drill holes in the area indicates that the Fish Creek coal pinches out to the north and northeast of the study site, probably following the trend of the Upper Cretaceous shoreline of that period.

Above the coal, Ryer has described a 6-ft sandstone interval. This is missing in the study site. The coal is overlain by mudstone.

A silty horizon, 2 to 7 ft above the coal, was selected as the dividing line between the Holderness and the overlying Lewis Shale for use in the geologic logs. It is not well enough defined to serve as a marker unit relating to the coal however. Neither can the sandstone underlying the coal be used with reliability to locate the coal, since it does not always occur. The coal itself remains the most identifiable horizon in the upper Holderness.

Some differentiation between the units overlying and underlying the coal does exist. Neither the sandstones below the coal and at the base of the Holderness nor the mudstone interval characterized by contorted infillings in the Holderness are present in the Lewis Shale in the study site. Presence of these units was therefore used to identify the Holderness. On this basis, rock encountered in DH-3 has been identified as Holderness. Reasonable certainty exists that this hole is in a position underlying the coal, and that the coal either has been removed by erosion or was never present in this place.

Lewis Shale

The Lewis Shale overlies the Williams Fork Formation everywhere but on the dip slope fringes of the Twentymile basin in the study site. In the drill holes, rock type of the Lewis has been identified as mudstone. Separation of "mudstone" from "claystone" or "siltstone" requires detailed particle size analysis not possible in the field. Use of the term to describe the Lewis Shale is based on field estimation of particle size and is intended to indicate the lack of visible bedding structures.

The rock is dark gray to black, depending upon the quantity of organic material present. Carbonaceous fragments may be finely disseminated or in clusters. The Lewis has been identified as marine by Ryer, based on its fossil assemblage. Fossils are scattered and include brachiopods, ammonites, and clams. The mudstone ranges from slightly carcareous to so calcareous that it becomes almost a limestone. It is interbedded with limestone laminae in places. The rock is quite cohesive and shows no shaly structure except where jointing and brecciation has produced some fissility. At these horizons, the rock is soft and clayey, with many thin clay layers.

Very little evidence of bedding structure is present, but instead the rock is almost massive. Ryer attributes the lack of sedimentary structure to bioturbation.

Further details of the stratigraphy of the units may be found in the geologic logs of drill holes in the Geology Appendix. The approximate location of the drill holes is shown on plate 1. The hardness scale used in the logs is the Bureau's field hardness scale.

TABLE 1

ROCK AND/OR SOIL MATERIAL HARDNESS AND COHESIVENESS CLASSIFICATION FOR USE IN GEOLOGIC LOGS

Subdivisions 1 through 4 are applicable to soils and the classification follows standard Bureau terms for cohesive soils.

1. Very Soft: Full length of thumb can be jammed into in-place materials. Will not support its own weight when saturated; e.g., beach sand or organic swamp muck.

2. Soft: Thumb can be inserted to knuckle, granular materials crush down completely and easily to individual grains.

3. Firm: In-place material can be thumb printed when moist.

4. Compact: (Equals hard in cohesive soils terminology.) Cannot be thumb printed. Beginning of cementation. Granular materials can be crushed in fingers, but may contain cemented aggregates difficult or impossible to crush in fingers; includes clay cemented material.

5. Poorly Cemented or Poorly Indurated: Does not break down or soften in water. Very difficult or impossible to crush in fingers, but edges can be scraped or crumbled, and grains rubbed off easily by hand.

6. Cemented or Indurated: Grains can be scraped off with fingernail or knife blade. One-half-inch lumps can be crushed with pliers, and there is a tendency for material to crush to powder. Nx core in 12-inch lengths can be broken in hands.

7. Well Cemented or Well Indurated: Only lumps smaller than 1/2-inch can be broken in pliers. When crushed there is a distinct tendency to break down to angular chips rather than individual grains.

8. Hard: Can be broken down to grains with a hammer, but does not ring.

9. Very Hard: Breaks through grains. Rings when hit with a hammer.

10. Hand specimen cannot be broken with hammer (rare).

Engineering Geology and Physical Properties

Soil material. All unconsolidated material above bedrock is considered soil for this study. It is primarily residual, but may include some slopewash. Among the holes drilled, the soil was 20 to 35 ft thick on the north facing slopes; 12 ft thick on level or south facing slopes.

Characteristics of soil developed on the Lewis Shale are consistent among drill hole locations. It is highly plastic and contains some bentonite. It forms compacted cohesive aggregates which disintegrate in water. The disintegration characteristic was used to differentiate soil from bedrock.

In some places, alluvium overlies the Lewis Shale. Here, a soil zone was differentiated from the alluvium by the color change, due both to presence of organic material and to weathering of minerals, and by a change in grain size.

Soil consistency was generally categorized by using the blow count data obtained when advancing the drill holes with a split spoon sampler. A field approximation of the standard penetration test can be made by using blow counts per foot for the last foot of each 1.5 ft interval. This approximation to foundation characteristics of soils should be used only as a semi-qualitative means to place the soil within a range of possible values. Blow counts per foot for residual soils on the Lewis Shale were greater than 30 below 3 ft and increased with depth. Values for alluvial soils varied from 10 to 30, depending on soil type regardless of depth. Using categories for sand (Terzhagi and Peck) the alluvial soils are firm to very firm; the residual soil over Lewis Shale is dense below 3 ft.

Plasticity of the Lewis soils is medium to high, giving the possibility of shrink-swell. Dessication cracks resulting from the shrink-swell are wider than 1 inch in some places. Where they are present, and slopes are steep, the potential for landslides exists when moisture increases. During reclamation of final slopes, minimizing shrink-swell may be desirable to enhance stability. Potential swell of clays increases with density and decreases with compaction moisture. Swell can be minimized by limiting compaction and increasing moisture content to the plastic limit during compaction.

Surface permeability is low. Road surfaces when wet become extremely slick. Only a thin layer is wetted if storms are of short duration, and roads dry rapidly.

Rock. The rock constituting the overburden is 95 to 99 percent mudstone, .5 to 5 percent limestone, and less than 1 percent clay. The mudstone is well cemented and cohesive and will require blasting for removal. Shape of fragments is expected to be blocky. Blasting can be expected to generate rock fragments up to 6 ft. Some fines will be generated; they will be highly plastic when wet.

During the strip-mining period, slope stability of mudstone in high walls should be good, with slopes of 1/2:1 when left open for a period of 2 weeks or less. However, clay layers in the mudstone may provide slide planes where dip of the beds is into the mining strip, particularly if such a plane lies below the water table.

During reclamation, slope stability of repositioned aggregates of rock fragments and clayey fines will be dependent upon the slope angle. Slopes of 1:1 varying up to 1-1/2:1 will be stable depending on the amount of fines.

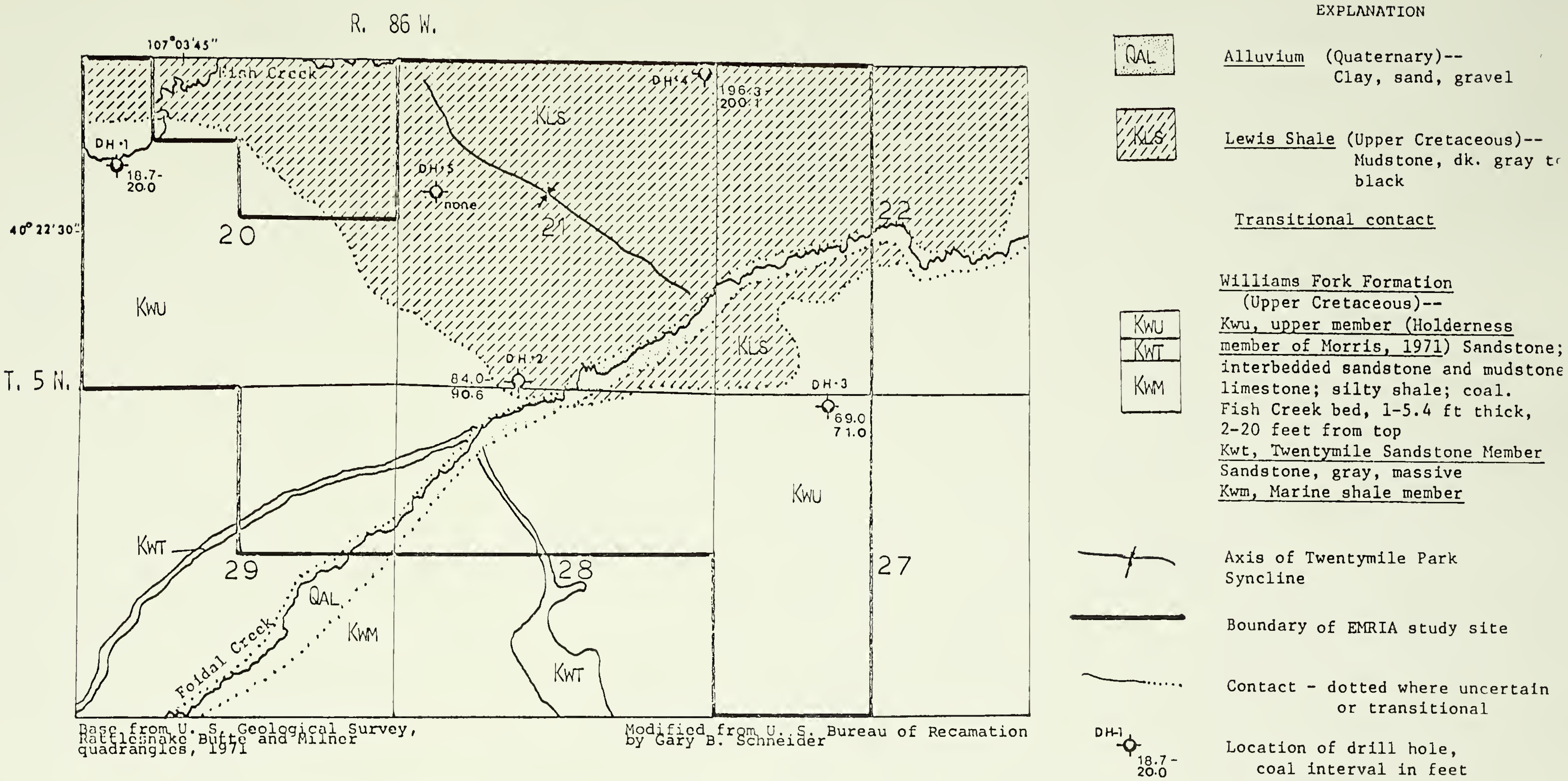
After 3 months of drying and freeze-thaw weathering, mudstone cores slaked to fragments .01 to .2 inch. Weathering in place of mudstone rock fragments after blasting can be expected to produce similar disintegration with resultant instability of slopes.

COAL

INTRODUCTION

The Fish Creek study site is an area of about 3.7 mi^2 between Fish Creek and Foidel Creek tributaries of the Yampa River. The site is within the Milner and Rattlesnake Butte 7-1/2-minute topographic quadrangles. Five holes were cored by Reclamation (figure 10). The Geological Survey sampled coal beds from these cores and submitted the coal samples to their laboratories for analysis. The results of the analyses are discussed in this coal section and reported later in the Coal Appendix.

The coal evaluated for this study--the Fish Creek coal bed, as much as 5.4 ft thick--is 2 to 20 ft below the top of the Holderness Member Morris (1971) of the Upper Cretaceous Williams Fork Formation (figure 11). The Holderness Member is a 200-ft sequence of sandstone, siltstone, shale, and coal that overlies the massive, gray, ledge-forming Twentymile Sandstone Member of the Williams Fork Formation. The Holderness Member is overlain by dark-gray to black marine mudstone of the Lewis Shale of Late Cretaceous age. Deeper coal-bearing rocks of the Iles Formation, below the Williams Fork, were not evaluated in this study.



Base from U. S. Geological Survey,
Rattlesnake Butte and Milner
quadrangles, 1971

Modified from U. S. Bureau of Recamation
by Gary B. Schneider

PRELIMINARY GEOLOGIC MAP OF THE FISH CREEK EMRIA STUDY SITE,
RATTLESNAKE BUTTE AND MILNER QUADRANGLES, ROUTT COUNTY, COLORADO.
1978

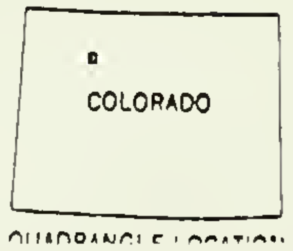


FIGURE 10

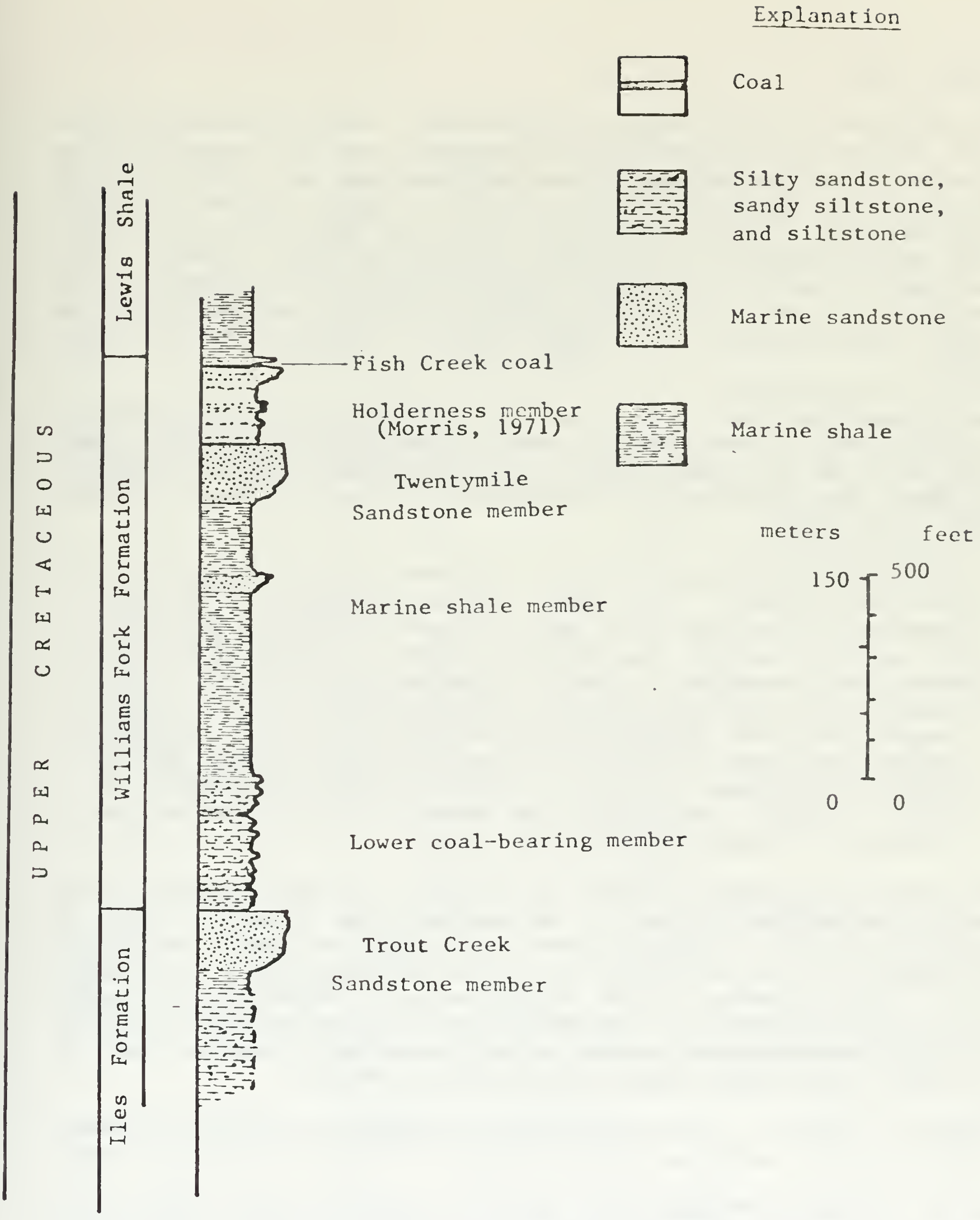

Explanation
Coal
Silty sandstone, sandy siltstone, and siltstone
Marine sandstone
Marine shale
meters
feet
150
500
0
0
UPPER CRETACEOUS
Lewis Shale
Williams Fork Formation
Iles Formation
Fish Creek coal
Holderness member (Morris, 1971)
Twentymile Sandstone member
Marine shale member
Lower coal-bearing member
Trout Creek Sandstone member

FIGURE 11. GENERALIZED STRATIGRAPHIC SECTION FISH CREEK EMRIA STUDY SITE, NORTHWESTERN COLORADO (MODIFIED FROM RYER, 1977).

RANK OF COAL

The position of a coal within the metamorphic series, which begins with peat and ends with graphocite, is dependent upon the temperature and pressure to which the coal has been subjected and the duration of time of subjection. Because it is, by definition, largely derived from plant material, coal is mostly composed of carbon, hydrogen, and oxygen, along with smaller quantities of nitrogen, sulfur, and other elements. The increase in rank of coal as it undergoes progressive metamorphism is indicated by changes in the proportions of the coal constitutients; the higher rank coals have more carbon and less hydrogen than the lower ranks.

Two standardized forms of coal analyses, the proximate analysis and the ultimate analysis, are generally used in the world today, though sometimes only the less complicated and less expensive proximate analysis is made. The analyses are described as follows (Bureau of Mines, 1965, p. 121-122):

> The proximate analysis of coal involves the determination of four constituents: (1) Water, called moisture; (2) mineral impurity, called ash, left when the coal is completely burned; (3) volatile matter, consisting of gases or vapors driven out when coal is heated to certain temperatures; and (4) fixed carbon, the solid or cokelike residue that burns at higher temperatures after volatile matter has been driven off. Ultimate analysis involves the determination of carbon and hydrogen as found in the gaseous products of combustion: the determination of sulfur, nitrogen, and ash in the material as a whole, and the estimation of oxygen by difference.

Most coals are burned to produce heat energy so the heating value of the coal is an important property. The heating value (calorific value) is commonly expressed in British thermal units (Btu) per pound: one Btu is the amount of heat required to raise the temperature of 1 lb of water 1° F. (In the metric system, heating value is expressed in kilogram calories per kilogram.) Additional tests are sometimes made, particularly to determine the caking, coking, and other properties, such as tar yield, which affect classification or utilization.

Figure 12 compares, in histogram form, the heating values and moisture, volatile matter, and fixed carbon contents of coals of different ranks.

Various schemes for classifying coals by rank have been proposed and used, but the most commonly used is entitled "Standard specifications for classification of coals by rank," table 2, adopted by the American Society for Testing and Materials (ASTM, 1974).

The ASTM classification system differentiates coals into classes and groups on the basis of mineral-matter-free fixed carbon or volatile matters and the heating value, supplemented by determination of agglomerating (caking) characteristics. As pointed out by the ASTM (1974, p. 55), a standard rank determination cannot be made unless

Table 2.--Classification of coals by rank[1]

[American Society for Testing and Materials Standard D388-66 (Reapproved 1972); 1 Btu equals 0.252 kilogram-calories. Leaders (---) indicate category is not used in rank determination of group]

Class	Group	Fixed carbon limits, percent (dry, mineral-matter-free basis)		Volatile matter limits, percent (dry, mineral matter-free basis)		Calorific value limits, Btu per pound (moist,[2] mineral-matter-free basis)		Agglomerating Character
		Equal or greater than	Less than	Greater than	Equal or less than	Equal or greater than	Less than	
I. Anthracitic	1. Meta-anthracite	98	---	---	2	---	---	nonagglomerating
	2. Anthracite	92	98	2	8	---	---	
	3. Semianthracite[3]	86	92	8	14	---	---	
II. Bituminous	1. Low volatile bituminous coal	78	86	14	22	---	---	commonly agglomerating[5]
	2. Medium volatile bituminous coal	69	78	22	31	---	---	
	3. High volatile A bituminous coal	---	69	31	---	14 000[4]	---	
	4. High volatile B bituminous coal	---	---	---	---	13 000[4]	14 000	
	5. High volatile C bituminous coal	---	---	---	---	11 500	13 000	
						10 500	11 500	agglomerating
III. Subbituminous	1. Subbituminous A coal	---	---	---	---	10 500	11 500	nonagglomerating
	2. Subbituminous B coal	---	---	---	---	9 500	10 500	
	3. Subbituminous C coal	---	---	---	---	8 300	9 500	
IV. Lignitic	1. Lignite A	---	---	---	---	6 300	8 300	
	2. Lignite B					---	6 300	

[1] This classification does not include a few coals, principally nonbanded varieties, that have unusual physical and chemical properties and that come within the limits of fixed carbon or calorific value of the high-volatile bituminous and subbituminous ranks. All of these coals either contain less than 48 percent dry, mineral-matter-free fixed carbon or have more than 15,500 moist, mineral-matter-free British thermal units per pound.

[2] Moist refers to coal containing its natural inherent moisture but not including visible water on the surface of the coal.

[3] If agglomerating, classify in low-volatile group of the bituminous class.

[4] Coals having 69 percent or more fixed carbon on the dry, mineral-matter-free basis are classified according to fixed carbon, regardless of calorific value.

[5] It is recognized that there may be nonagglomerating varieties in these groups of the bituminous class and that there are notable exceptions in the high-volatile C bituminous group.

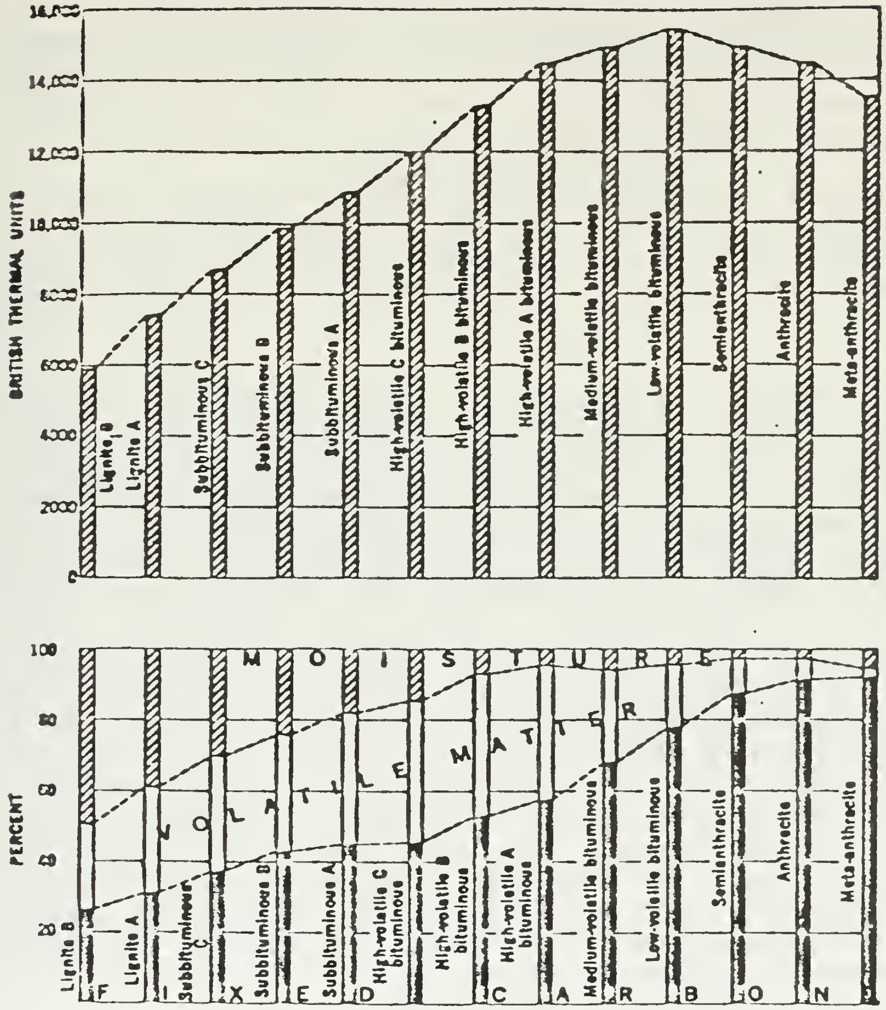


FIGURE 12. --COMPARISON ON MOIST, MINERAL-MATTER-FREE BASIS OF HEAT VALUES AND PROXIMATE ANALYSES OF COAL OF DIFFERENT RANKS

(1974, p. 55), a standard rank determination cannot be made unless the samples were obtained in accordance with standardized sampling procedures (Snyder, 1950 and Schopf, 1960). However, nonstandard samples may be used for comparative purposes through determinations designated as "apparent rank."

Three samples listed on tables 3 and 4 show an apparent rank of bituminous C. Because of the lack of definitive information about the distribution of coals of various groups in the Fish Creek coal, it is considered to be all bituminous C in rank in the area of the study.

TYPE OF COAL

Classification of coals by type--that is, according to the types of plant materials present--takes many forms, such as the rational analysis of Francis (1961) or the semicommercial type classification commonly used in the coal fields of the eastern United States (Bureau of Mines, 1965, p. 123). However, most of the type classifications are based on the same, or similar, gross distinctions in plant material as those used by Tomkeieff (1954, table 2, p. 9), who divided the coals into three series: humic coals, humicsapropelic coals, and sapreopelic coals, based upon the nature of the original plant materials. The humic coals are largely composed of the remains of the woody parts of plants; and the sapropelic coals are largely composed of the more resistant waxy, fatty, and resinous parts of plants, such as cell walls, spore-coatings, pollen, resin particles, and coals composed mainly of algal material. Most coals fall into the humic series, with some coals being a mixture of humic and sapropelic elements and, therefore, falling into the humic-sapropelic series. The sapropelic series is quantitatively insignificant and, when found is commonly regarded as an organic curosity. Coals from Fish Creek fall largely in the humic series, which is in common with most of the United States coals.

GRADE OF COAL

Classification of coal by grade or quality is based largely on the content of ash, sulfur, and other constituents that adversely affect utilization. Most detailed coal resource evaluations of the past do not categorize known coal resources by grade, but coals of the United States have been classified by sulfur content in a gross way (DeCarlo and others, 1966).

The range and average of the ash and sulfur content of 642 coals from all parts of the United States were determined by Fieldner, Rice, and Moran (1942).

Ash and sulfur contents of U.S. coals on an as-received basis

Number or samples	Ash, percent		Sulfur, percent	
	Range	Average	Range	Average
642	2.5-32.6	8.9	0.2-7.7	1.9

Table 3.--USGS sample number, hole number, and depth interval, for three core coal samples, Fish Creek EMRIA study site, Routt County, Colorado.

[All samples are from the Fish Creek coal bed, Williams Fork Formation of Late Cretaceous age]

USGS sample number	Hole number	Location	Depth interval, feet and (meters)
D186056	1	SW¼ NW¼ sec. 20, T. 5 N., R. 86 W.	18.7-20.0 (5.7-6.1)
D186057	2	SE¼ SW¼ sec. 21, T. 5 N., R. 86 W.	84.0-89.9 (25.6-27.4)
D186058	4	NE¼ NE¼ sec. 21, T. 5 N., R. 86 W.	196.7-200.1 (60.0-61.0)

TABLE 4

Proximate and ultimate analyses, heat of combustion, forms-of-sulfur, free-swelling-index, and ash fusion temperature determinations for three coal samples from the Fish Creek Study Site

[All analyses except Kcal/kg, free swelling index and ash fusion temperatures in percent. For each sample number, the analyses are reported three ways: first, as received; second, moisture free; and third, moisture and ash free. All analyses by Coal Analysis Section, U.S. Bureau of Mines, Pittsburgh, PA. °C = (°F-32) 5/9; Kcal/kg = (0.556) Btu/lb]

Sample number	Proximate Analyses				Ultimate Analyses					Heat of combustion	
	Moisture	Volatile matter	Fixed Carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Kcal/kg	Btu/lb
D186056	10.3	36.0	43.9	9.8	5.3	61.3	2.0	19.9	1.7	6,050	10,880
	----	40.1	49.0	10.9	4.6	68.4	2.2	12.0	1.9	6,745	12,130
	----	45.0	55.0	----	5.2	76.8	2.5	13.5	2.1	7,565	13,610
D186057	10.8	34.9	37.1	17.2	4.9	55.3	1.7	18.7	2.2	5,450	9,800
	----	39.2	41.5	19.3	4.2	62.0	1.9	10.1	2.4	6,110	10,990
	----	48.5	51.5	----	5.2	76.8	2.4	12.6	3.0	7,570	13,620
D186058	9.8	35.9	47.8	6.5	5.6	65.6	1.9	18.6	1.8	6,495	11,680
	----	39.8	53.0	7.2	5.0	72.7	2.2	10.9	2.0	7,205	12,960
	----	42.9	57.1	----	5.3	78.4	2.3	11.8	2.2	7,760	13,960

Sample number	Air-dried loss	Forms of Sulfur			Free swelling index	Ash Fusion Temperature C°		
		Sulfate	Pyritic	Organic		Initial deform.	Soften.	Fluid
D186056	2.6	0.02	0.81	0.85	0.0	1,105	1,155	1,220
		.02	.90	.95				
		.02	1.01	1.06				
D186057	2.2	.03	1.43	.71	.0	1,125	1,175	1,240
		.03	1.60	.80				
		.04	1.98	.99				
D186058	2.1	.02	1.62	.17	.0	1,045	1,100	1,160
		.02	1.79	.18				
		.02	1.93	.20				

The ash and sulfur content of the three coal samples from the Fish Creek coal, as received, are ash range, 6.5 to 17.2 percent; average, 11.1 percent; sulfur-range, 1.7 to 2.2 percent; average, 1.9 percent.

ESTIMATION AND CLASSIFICATION OF COAL RESOURCES

Coal resource estimates have been prepared for the Fish Creek coal within the study site using standard procedures, definitions, and criteria established by Geological Survey and Bureau of Mines for making coal resource appraisals in the United States. The term "coal resources," as used in this report, means the estimated quantity of coal in the ground in such form that economic extraction is currently or potentially feasible.

TABULATION OF ESTIMATED COAL RESOURCES

Table 5 summarizes the estimated coal resources of the Fish Creek study site. The resources in the study site are classed as measured, indicated, and inferred according to the degree of geologic assurance of the estimate. These classifications are explained below:

Measures. Resources are computed from dimensions revealed in outcrops, trenches, mine workings, and drill holes. The points of observation and measurement are so closely spaced and the thickness and extent of coals are so well defined that the tonnage is judged to be accurate within 20 percent of true tonnage. Although the spacing of the points of observation necessary to demonstrate continuity of the coal differs from region to region according to the character of the coal beds, the points of observation are no greater than 1/2 mi apart. Measured coal is projected to extend as a 1/4-mi-wide belt from the outcrop or points of observation or measurement.

Indicated. Resources are computed partly from specific measurements and partly from projections of visible data for a reasonable distance on the basis of geologic evidence. The points of observation are 1/2 mi to 1-1/2 mi apart. Indicated coal is projected to extend as a 1/2-mi-wide belt that lies more than 1/4 mi from the outcrop or points of observation or measurement.

Inferred. Quantitative estimates are based largely on broad knowledge of the geologic character of the bed or region, because few measurements of bed thickness are available. The estimates are based primarily on an assumed continuation from measured and indicated coal for which geologic evidence exists. The points of observation are 1-1/2 mi to 6 mi apart. Inferred coal is projected to extend as a 2-1/4-mi-wide belt that lies more than 3/4 mi from the outcrop or points of observation measurement.

All of the estimated resources in beds thicker than 5 ft and at depths of 1,000 ft or less fall into a category called "reserve base," which is defined as that portion of the identified coal resource from which reserves are calculated. Reserves are that portion of the identified

TABLE 5

Estimated identified coal resources of the Fish Creek coal bed, Fish Creek site, Routt County, Colorado

[1 foot = 0.305 meters; 1 short ton = 0.907 metric tons]

Section	0-200 feet overburden								
	2 1/2-5 feet Coal				5-10 feet Coal				Section Total
	Measured	Indicated	Inferred	Total	Measured	Indicated	Inferred	Total	
20, NW1/4NW1/4, S1/2NW1/4, S1/2	32	1,654	38	1,724	---	---	---	---	1,724
21, all	866	1,837	---	2,703	488	674	---	1,162	3,865
22, W1/2	387	1,521	---	1,908	147	206	---	353	2,261
27, W1/2	350	1,027	384	1,761	---	---	---	---	1,761
28, N1/2	229	919	---	1,148	13	---	---	13	1,161
29, NE1/4	---	132	85	217	---	---	---	---	217
Grand totals	1,864	7,090	507	9,461	648	880	---	1,528	10,989

coal resource that can be economically mined at the time of determination. The reserve is derived by applying a recovery factor to that component of the identified coal resource designated as the reserve base. On a national basis the estimated recovery factor for the total reserve base is 50 percent. More precise recovery factors can be computed by determining the total coal in place and the total coal recoverable in any specific locale.

CHARACTERISTICS USED IN RESOURCE EVALUATION

The coal characteristics commonly used in classifying coal resources are the rank, grade, and weight of the coal: the thickness of the coal beds: and the thickness of the overburden. Rank and grade have been discussed previously. Weight and thickness are explained below:

Weight. The weight of the coal ranges considerably with differences in rank and ash content. In areas such as Fish Creek, where true specific gravities of the coal have not been determined, an average specific gravity value based on many determinations in other areas is used to express the weight of the coal for resource calculations. The average weight of bituminous coal is taken as 1,800 tons/acre-ft, a specific gravity of 1.32.

Thickness of beds. Because of the important relationship of coal-bed thickness to utilization potential, most coal resource estimates prepared by Geological Survey are tabulated according to three thickness categories. Because the coal evaluated in this report is so close to the bituminous-subbituminous division of rank, the thickness categories used are thin, 2.5 to 5 ft; intermediate, 5 to 10 ft; and thick, more than 10 ft. About 86 percent of the estimated resources of the study area is in the thin category and about 14 percent is in the intermediate category. Averitt, (1975, figure 5, p. 37) by way of comparison, showed the distribution of the estimated resources of 21 states as 42 percent in the thin category, 25 percent in the intermediate category, and 33 percent in the thick category.

THICKNESS OF OVERBURDEN

All of the estimated coal resources in the Fish Creek study site are overlain by 200 ft or less of overburden. No coal deeper than 200 ft was evaluated.

SUMMARY OF RESOURCES

Total estimated identified original resources in the Fish Creek study site are 10,969,000 tons. The coal-bed thickness class of 2.5 to 5 ft contains 9,461,000 tons. The coal-bed thickness class of 5 to 10 ft contains 1,528,000 tons of the estimated resources. Maximum measured thickness of the coal bed is 5.4 ft.

The estimated resources presented in this report are original resources; that is, resources in the ground before the beginning of mining operations.

INTERPRETATIONS FOR SOIL AND BEDROCK MATERIAL AS A POTENTIAL SOURCE FOR REVEGETATION

MAJOR SOIL BODIES

The major physiographic units of the Fish Creek study site are (1) long upland slopes dissected by small intermittent drainages, (2) smoothly rounded hills and ridges of uplands occurring on the shale formations between Foidel and Fish Creeks, (3) nearly level to gently sloping fans, and (4) flood plains along perennial streams in the area. The following general descriptions are of the soils and topography associated with these physiographic units.

Upland Slopes

This physiographic unit is dominated by cuestas having steep faces exposing the more resistant geologic material. On the other side of the apex these cuestas have long gradual slopes. The northeasterly facing slope south of Foidel Creek, in particular, includes areas of uplifted sandstone ridges, oriented in a north-south direction. Between the uplifts are pockets of relatively coarse-textured material derived from wind and water sorted materials.

The majority of the soils included in this group are formed in residuum weathered from sandstone. Such soils support a relatively productive plant cover and is the only unit which is dominated by aspen and mountain foothill-type shrubs. The soil depth is usually more than 48 inches to bedrock. The soils are of medium and moderately fine textures such as silt loam, loam, and sandy clay loam. Water holding capacities generally exceed 2 in/ft. Major portions of this unit are comprised of soils which have moderate permeability and infiltration. Some minor areas of coarser-textured material are included in this unit which have moderately rapid to rapid rates of permeability and moderately rapid surface infiltration rates due to the coarse-textured surface layers. Structural grades of these soils are strong as characterized by the mature and well developed profiles. Therefore, they should be quite stable even after disturbance has occurred. Laboratory screening tests indicate that the electrical conductivity is generally less than 1 mmho/cm, and exchangeable sodium is well below 10 percent. The pH values range from 5.0 to 7.5. These soils are well suited as a source of plant growth medium.

Hills and Ridges

The parent material (Lewis Shale) is the dominant factor related to soil development in this physiographic unit. These soils are brown silty clays and clays with water-holding capacities ranging from 2 to 3 in/ft. Permeabilities are slow because of their fine textures. Moderately slow infiltration rates (less than 0.25 in/h) are typical of these soils. Due to this slow infiltration rate and moderately steep gradients, major losses of topsoil have resulted from erosion by water. Structural grades are moderately strong in the upper 2 ft of their profile and range from weak to massive in the lower portions. Soil depths range from 32 to 54 inches over consolidated or slightly weathered paralithic shales and sandstones.

Electrical conductivities of the 1:5 extract are generally low (0.07 to .20 mmho/cm) as are the exchangeable sodium percents (0.17 to 4.0) for the soil layers of representative soils in this category. The pH values ranged from 6.5 to 8.3. These soils have a poor suitability for use as a growth media; the primary limiting factor being the soil-water relationships due to silty clay and clay textures.

Fans

Soils occurring on the nearly level to gently sloping fans are deep. In most profiles examined, shale or sandstone was encountered below 48 inches. These soils are developing in residuum on old fan terraces and are dominated by silt and sand size particles and include loams, silt loam, and silty clay loam textures. The permeability rate is medium and the water holding capacity ranges from 1.4 to 2.5 in/ft of depth. Due to fine sandy loam and loam surface layers, the infiltration rates are moderate and range from 0.3 to 0.75 in/h. Structural grades, particularly in the upper 3 ft are strong. A few profiles within this group have some mottling reflecting somewhat poor drainage due to the impervious nature of the underlying sandstone. Because these soils will not be used in place, this characteristic is not felt to be a limiting factor. The electrical conductivity of the 1.5 extract is low, ranging from .02 to 0.7 mmhos/cm. The reaction (pH) of the soils range from 5.9 to 7.5 and exchangeable sodium percentage is low. Soils of this group are generally highly suited as a planting media.

Flood Plains

Soils of this physiographic unit are deep, somewhat poorly drained and generally have appreciable levels of salinity and/or sodicity. The individual soil profiles reflect a moderate degree of stratification and mottling indicating that high water tables are periodically present.

Soil textures include loam, clay loam, silt loam, silty clay loam, silty clay, and clay. The medium textures predominate. Permeabilities are generally moderately slow to very slow. Infiltration rates range from moderate to slow and structural grades are generally weak, since alluvial deposition is recent and continuing. Sodic problems (ESP greater than 15) generally were found to occur on the flood plain of Fish Creek due to the influence of the Lewis Shale which is sodic in nature in the immediate area. Those profiles representative of the Foidel Creek flood plain were nonsodic. Although some profiles had significant levels of salinity (4 to 12 mmhos/cm) most profiles were not seriously affected by salt concentration. Because of combinations of clayey textures, slow permeabilities, salinity, or sodium, these soils are deemed unsuitable for use as a planting medium.

OVERBURDEN CHARACTERISTICS

Land Suitability

A detailed land suitability survey was made of the study area to characterize and evaluate the surface and underlying material (10 ft) in relation to its suitability as a source of planting media for resurfacing shaped spoils following surface mining. This survey provided data on the quality and quantity of surface material for revegetation and the ease of stripping and stockpiling. Basic data on the present physical and chemical properties of the soils (upper 10 ft) are also provided by the study.

Land classification specifications were developed specifically for this study area to establish ranges of land suitability as a source of planting media. Soil factors included in the specifications for quality consideration were texture, salinity, sodicity, permeability, available water holding capacity, and erosion hazard. Quantity considerations were primarily the depth and geographic extent of suitable material. Excessive slope and depth to bedrock outcrops were factors considered in relation to ease of stripping and stockpiling of material. The land classification specifications for the Fish Creek study are given in table 6.

Four land suitability classes (1, 2, 3, and 6) were developed and correspond to the classes used in the Bureau land classification system. Class 1 lands are the most desirable as a source of topsoil for surfacing shaped spoils. Based on the criteria established for class 1, those lands will supply a large quantity of highly suitable material. This material can be easily stripped and stockpiled for postmining use on the lands they occupy and possibly for adjacent areas where topsoiling material was found inadequate. Class 2 lands have adequate resurfacing material, but which may require good placement practices to meet such requirements. These lands are less desirable in quality or more difficult to strip and stockpile than class 1 lands. Class 3 lands are marginal in their suitability for reclaiming mined areas because of poorer quality soil material and/or lesser available quantities. With good procedures for stripping and stockpiling, land in this class will meet the requirements, both quantitative and qualitative for shaping and revegetating. Class 6 lands generally do not have adequate or suitable material for topsoil use or if available should not be stripped and stockpiled. If class 6 lands are disturbed by surface mining, it will be necessary to borrow suitable material or improve the available material for revegetation to be successful. A composite land suitability map is shown on plate 3, and the land suitability summary is given on table 7.

Procedures

Field mapping was done on aerial photographs with an approximate scale of 1:17000. Geological Survey quadrangle, 7.5-minute series, topographic maps having a scale of 1:24000 with 40-ft contour intervals were used for location and reference when mapping the land.

LAND CLASSIFICATION SPECIFICATIONS - SURFACE MINE RECLAMATION [1/]
Suitability of Overburden for Revegetation of Surface-Mine Areas
BLM/WPRS Cooperative Program EMRIA
Fish Creek Study Site

Overburden Characteristics	Symbols Basic Subclass	Symbols Inform. & Defic.	Class 1	Class 2	Class 3
SOILS AND/OR BEDROCK TEXTURES	s		Sandy loams to clay loams	Sandy loam to silty clay loams	Loamy fine sand to clay
Coarse		v		Sandy loams sufficiently coarse to slightly reduce moisture retention, productivity, and may increase erosiveness.	Loamy sand in sufficient quantity to moderately reduce moisture retention, productivity, and may increase erosiveness.
Fine		h		Silty clay loam and clay-place below 12 inches in a reconstructed profile.	Silty clay laom and clay - place below 6 inches in a reconstructed profile.
Available Water Holding Capacity		q	2.0 inches per foot of soil	1.25 inch per foot of soil	More than 0.75 inches per foot of soil
Permeability		p	Adequate to provide a well drained and aerated root zone and an infiltration rate adequate to prevent serious erosion.	May be slightly restricted resulting in decreased drainage and aeration in the lower root zone and at reduced infiltration rate.	Restricted to extent that internal drainage may limit choise of plant species and/or require special practices to control erosion hazard.
Salinity		s	Less than 4 mmhos per centimeter	Less than 8 mmhos	Less than 12 mmhos
Sodicity		a	Less than 10 ESP-may be higher if hydraulic conductivity meets limits for Class 1	Less than 10 ESP-may be higher if hydraulic conductivity meets limits for Class 2	Less than 15 ESP-may be higher if hydraulic conductivity meets limits for Class 3

TABLE 6
page 1 of 3

Overburden Characteristics	Symbols Basic Subclass	Symbols Inform. & Defic.	Class 1	Class 2	Class 3
Erodibility			Subject to slight erosion	Susceptible to moderate erosion	Susceptible to severe erosion but can be controlled with proper management
Depth		b	36 inches or more of overburden that is suitable for plant media.	24 inches or more overburden that is suitable for plant media	6 inches or more overburden 2/ that is suitable for plant media.
TOPOGRAPHY	t				
Slope 3/		g	Less than 20 percent	Less than 20 percent	Less than 25 percent - can be greater in areas situated at uphill ends of excavated strips where these materials are customarily used.
Bedrock outcrops 3/		r	Will not affect stripping or quantity of suitable material.	Numerous enough to reduce quantity of suitable material slightly and make stripping more expensive.	Numerous enough to reduce quantity of suitable material appreciably and make stripping considerably more expensive.
Weatherability 4/		w	Breaks down readily upon exposure to normal weathering in the surface environment	May require a short to moderate period to break down following exposure.	May require an extended period to break down into optimum particle size distribution but is usable in a practically acheivable state in a reasonable time period

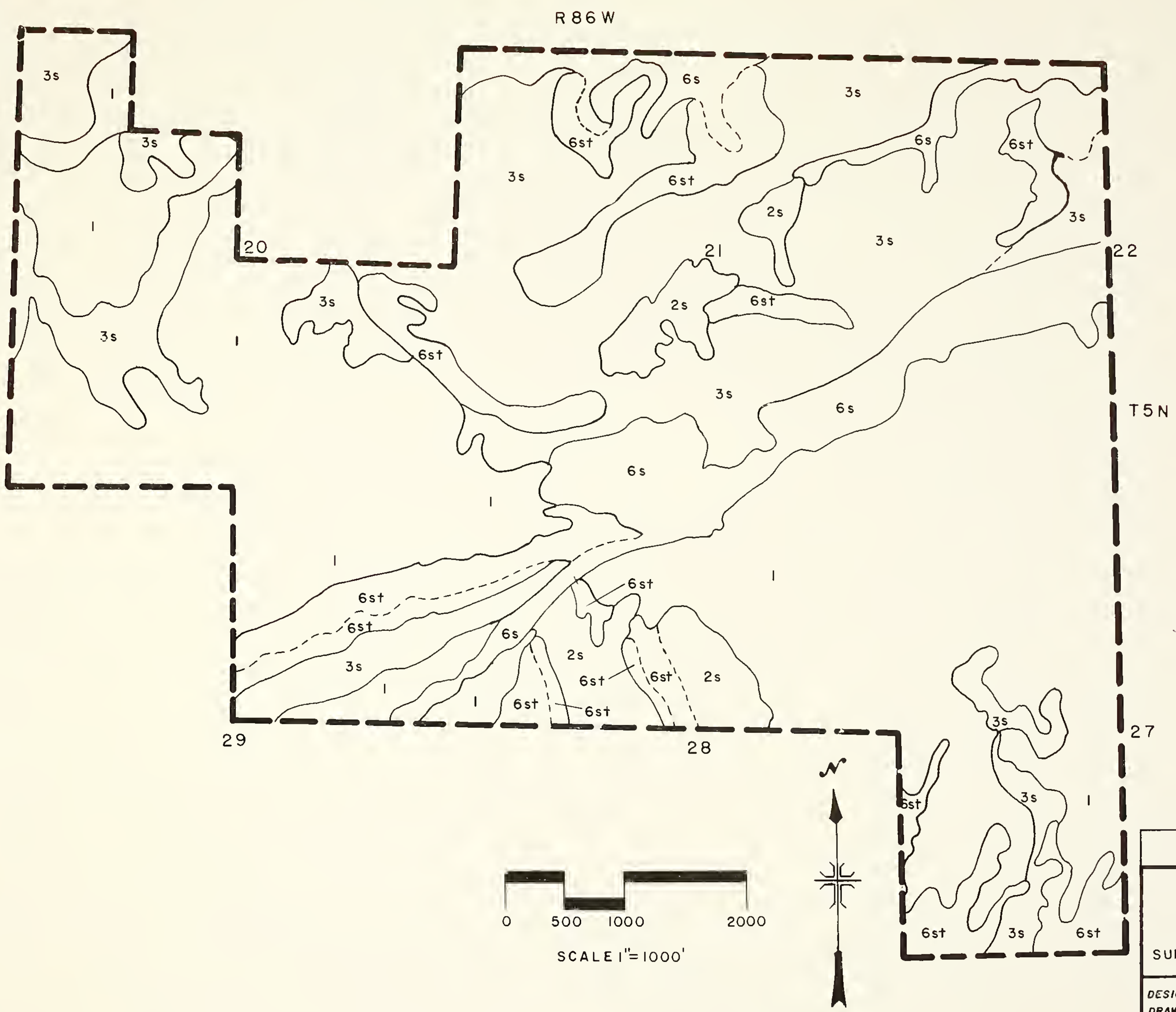
Overburden	Symbols Basic Subclass	Symbols Inform. & Defic.	Class 1	Class 2	Class 3
DRAINAGE	Because of land alterations by surface mining, present drainage conditions (with the exception of active streams and their immediate flood plains) are not a factor in the classification. Permeability requirements are covered under Soils.				
Class 6	All areas not meeting requirements for Classes 1, 2, or 3. These lands are unsuited in their present condition as a source of material for revegetation.				

1/ Specifications are based on natural rainfall or minimum irrigation for starting and establishing plantings.
2/ Six inches is considered as the minimum strippable depth.
3/ Related primarily to ease of stripping operations.
4/ Weatherability is applicable only to bedrock or consolidated material.

Table 7.--Land Suitability Summary

CLASS	Section - Township north - Range west 20-5-86	21-5-86	22-5-86	27-5-86	28-5-86	29-5-86	Total acres	Percent of study area
1	301.0	30.6	119.3	236.2	176.8	88.3	952.2	43.3
2s	-	36.0	-	-	52.1	-	88.1	4.0
3s	123.6	379.5	118.3	33.8	7.9	28.3	691.4	31.4
6s	-	107.5	68.8	-	35.5	2.9	214.7	9.8
6st	15.4	86.4	13.6	50.0	47.7	40.5	253.6	11.5
TOTALS	440.0	640.0	320.0	320.0	320.0	160.0	2,200.0	100.0

CLASS	SECTION - TOWNSHIP NORTH - RANGE WEST 20-5-86	21-5-86	22-5-86	27-5-86	28-5-86	29-5-86	TOTAL ACRES	PERCENT OF STUDY AREA
1.	301.0	30.6	119.3	236.2	176.8	88.3	952.2	43.3
2s	–	36.0	–	–	52.1	–	88.1	4.0
3s	123.6	379.5	118.3	33.8	7.9	28.3	691.4	31.4
6s	–	107.5	68.8	–	35.5	2.9	214.7	9.8
6st	15.4	86.4	13.6	50.0	47.7	40.5	253.6	11.5
TOTALS	440.0	640.0	320.0	320.0	320.0	160.0	2200.0	100.0



ALWAYS THINK SAFETY

FISH CREEK STUDY SITE
COMPOSITE LAND SUITABILITY

LANDS WERE CLASSED FOR THEIR SUITABILITY AS A SOURCE OF PLANTING MEDIA

DESIGNED ____ TECH. APPROVAL ____
DRAWN L. PETERSON SUBMITTED A. SHINEMAN
CHECKED T. CAPPELLUCCI ADMIN. APPROVED ____

DENVER, COLORADO

PLATE 3

Representative sites were examined to 10 ft and sampled to a depth of 5 ft except where the existence of hard geologic materials rendered it impractical to do so. This information was supplemented by nonrecorded profile examinations as required. The soil profiles were examined by excavating the soil with a tile spade and an orchard handauger. Soil structure, consistence, texture, color, root distribution, and other physical features of the profile were observed on the representative sites recorded. Salinity and sodicity were based primarily on laboratory analyses of samples collected from representative profiles.

Many of the observable characteristics such as texture, structure, consistency, salinity, and sodicity were directed toward estimating soil-moisture relationships of the material. A tentative land suitability class was established by using these basic soil characteristics combined with observations of other land features such as stones, exposed indurated bedrock, and slope. The final land class was determined after evaluating the laboratory data along with the observational information.

Results of the land suitability survey show that approximately 79 percent of the study area has adequate material for postmining reclamation purpose. Deficiencies observed during the survey were fine textures, steep slopes, bedrock outcrops, coarse fragments, salinity, sodicity, and insufficient quantities of strippable material. Table 7 summarizes the acreages of the land subclasses delineated by the study. Figures C1 through C6 in appendix C show the results of the land classification by section. The profile logs with related laboratory data, location, parent material, and pertinent remarks are also given.

The land suitability survey provides adequate data for developing lease stipulations regarding the reclamation portion of the required mining plan. It does not, however, provide adequate detail for stripping and stockpiling operations immediately prior to the surface mining. It may be desirable to obtain more detailed information through additional soil borings, observations, and supporting laboratory data. A procedure similar to that used in the land classification could then be used to determine the quantity, quality, and locations of the available material suitable to be stockpiled for planting media. A description of the major land classes in the land suitability survey is as follows:

Class 1. Lands in this class have a minimum depth of 36 inches of good quality soil that is suitable for plant media. These soils are forming generally in residuum. The dominant textures are loam, sandy clay loam, and silt loam. Aggregate stability in the soil solum is strong and water enters the profiles readily. Internal drainage is moderate and adequate moisture is stored for plant use. These soils are nonsaline and nonsodic. They are generally noncalcareous in the upper 36 inches of the soil profile and only slightly calcareous from 3 to 5 ft.

Land features. Class 1 lands in the study site include (1) gently sloping upland fans and sloping hillsides, and (2) a long steep north-facing slope on the uplift area between Foidel and Fish Creeks.

Class 2. All lands classified as class 2 in the study site were done so solely because of soil deficiencies. Thus only the subclass "s" was used.

Subclass 2s. Lands in subclass 2s are of two distinct types: (1) moderately fine textured soils with restricted permeabilities, and (2) moderately coarse textured soils which have a relatively high erosion hazard. Levels of sodium and salinity are low and pose no serious problems.

Land features. Subclass 2 lands are minor in extent. Two distinct types exist: (1) knobs and isolated hills, and (2) wind deposited fill between the edges of an uplift.

Class 3. All lands classified as class 3 were on the basis of soil deficiencies; thus, only the subclass "s" was used.

Subclass 3s. Lands in this subclass are primarily fine textured (silty clay and clay). Also, a few small areas occur which have an average minimum depth of 6 inches moderately coarse or medium textured soil material overlying impervious sandstone. These soils are generally nonsodic and nonsaline.

Land features. The primary land feature represented consists of sloping to steep hills and associated ridge crests north of Foidel Creek.

Class 6. Lands in this class are unsuitable for use as a source of planting media. Two subclasses, one having a soils deficiency and the other a soils and topography deficiency, are recognized.

Subclass 6s. A limited acreage falls into this subclass. These lands are located adjacent to Fish and Foidel Creeks. Soils of these lands are not suited in their present condition for use as a plant growth medium because of salinity, sodicity, and restricted permeability rates (or combinations thereof). In some profiles, the exchangeable sodium exceeds 15 percent, in others the electrical conductivity of the saturation extract ranged from 4 to 14 mmhos/cm. Because these soils are water deposited, the profiles are highly stratified. The soil textures are generally moderately coarse to medium.

Land features. The lands within the study site are nearly level flood plains of ephemeral streams in the study area.

Subclass 6st. - Within this subclass are lands which have (1) no soil material or less than 6 inches of soil overlying hard sandstone, and (2) soils that contain substantial amounts of coarse fragments (flagstone and cobble) large enough to hinder stripping operations. Both soil conditions may be found on slopes of more than 25 percent. Included in this subclass are rather small areas which have very heavy soil textures occurring on steep slopes.

Land features. Steep cuesta faces and slopes are included along with higher portions of upland ridges, sideslopes, and escarpments.

Overburden Evaluation (10 ft to bottom coal seam)

The land suitability survey classifies lands for their suitability as a source of planting media taking into consideration many factors including soil depth up to at least 10 ft. If adequate topsoil or suitable soils are unavailable, suitable overburden materials may be considered. An attempt was made to evaluate the overburden material for use as a planting medium based on data derived from chemical and physical laboratory tests performed on core taken from five deep hole borings drilled on the site. The quality evaluations apply to the specific core site.

Because of the limited number of holes drilled and the diverse nature of the geologic material, the quality evaluations of core overburden cannot be projected accurately between drill hole locations.

The suitability of overburden material was rated on a broad scale as suitable, limited, or unsuitable. Applicable parts of the specifications used for the land suitability survey given in table 6 were used to provide criteria for the ratings. The suitable rating is equivalent to class 1 and the best of class 2, the limited rating to the lower part of class 2 and class 3, and the unsuitable rating to class 6.

Results of the core evaluations are presented below:

Deep Hole No. 1

Depth (ft)	Material	Evaluation	Remarks
0-7.5	Clay	Suitable	
7.5-12.8	Clay-shale	Suitable	
12.8-13.6	Mudstone	Suitable	
13.6-18.7	Siltstone	Suitable	
18.7-20.3	Coal	Unsuitable	
20.3-25.0	Limestone-mudstone	Limited	Sodic - coaly
25.0-30.0	Mudstone	Suitable	

The material above the coal was evaluated suitable. The limestone below the coal graded to mudstone with depth and contained coal fragment at 21.0 ft.

Deep Hole No. 2

Depth (ft)	Material	Evaluation	Remarks
0-5.0	Clay	Limited	Fine textured [1] salinity
5.0-14.0	Clay	Limited	Fine textured[1]
14.0-20.0	Mudstone	Limited	Permeability
20.0-24.5	Mudstone	Unsuitable	High ESP
24.5-69.3	Mudstone	Unsuitable	High ESP
69.3-78.6	Limestone	Unsuitable	High ESP
78.6-84.0	Mudstone	Unsuitable	High ESP
84.0-90.6	Coal	Unsuitable	
90.6-115.0	Sandstone	Unsuitable	Permeability, High SAR

The overburden materials below 115.0 ft were not sampled for the laboratory as the hole terminated 25 ft below coal (90.6 ft). However, a geologic drilling survey continued to 283 ft.

Deep Hole No. 3

Depth (ft)	Material	Evaluation	Remarks
0-7.0	Sandy loam	Suitable	
7.0-18.0	Sandy	Limited	Coarse textured [2]
18.0-28.2	Sandy	Limited	Coarse textured [2]
28.2-37.0	Sandy	Limited	Gravel, same clay stratified
37.0-52.5	Sandstone	Limited	Coarse textured [2]
52.5-92.0	Mudstone and sandstone	Unsuitable	Coaly
92.0-140.0	Mudstone	Unsuitable	Fine textured
140.0-160.8	Sandstone and mudstone	Limited	Low permeability

The hole terminated at 160 ft at sandstone known to underlie coal. Most of the materials to 37.0 were coarse textured including thin layers of gravely material. These coarse materials, other than the 0-7.0-ft layer, exhibited reduced and or restricted permeabilities when tested in the laboratory for disturbed hydraulic conductivities indicating a potential for high SAR values.

[1] Fine textured indicates problems with restricted infiltration and internal drainage if used on the surface for reclamation purposes.

[2] Coarse textured indicates low cation exchange capacity, high or excessive permeability, and limited available water-holding capacity.

Deep Hole No. 4

Depth (ft)	Material	Evaluation	Remarks
0-5.5	Clay	Limited	Fine textured [1]
5.5-10.0	Clayey	Limited	Fine textured [1]
10.0-17.5	Clayey	Limited	Fine textured [1] except for 15.5-17.5 ft (gravel)
17.5-35.0	Shale and mudstone	Limited	Fine textured [1]
35.0-56.3	Mudstone	Unsuitable	High SAR values
56.3-194.8	Mudstone	Unsuitable	High SAR values
194.8-196.3	Siltstone	Unsuitable	High SAR values
196.3-200.1	Coal	Unsuitable	
200.1-210.3	Mudstone and sandstone	Unsuitable	Coaly, high SAR values

The overburden material below 35.0 ft had very high sodium content with average SAR values of 47 for 27 intergradations through 210.3 ft.

Deep Hole No. 5

Depth (ft)	Material	Evaluation	Remarks
0-5.0	Silty clay	Limited	Slightly saline
5.0-17.2	Silty loam	Limited	Slightly saline med. SAR values
17.2-38.3	Mudstone	Unsuitable	High SAR values
38.3-108.0	Mudstone	Unsuitable	High SAR values
108.0-150.0	Mudstone (interbedded limestone)	Unsuitable	High SAR values
150.0-179.5	Mudstone	Unsuitable	High SAR values
179.5-197.5	Mudstone	Unsuitable	High SAR potential

The core material below 17.2 ft had high SAR values and were extremely sodic. Care should be given when stripping these types to prevent contamination of suitable materials.

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[1] Fine textured indicates problems with restricted infiltration and internal drainage if used on the surface for reclamation purposes.

Laboratory Support

Chemical and physical characterizations of genetic soil profiles and bedrock materials were an important aspect of analyzing the material resources of the Fish Creek study site. Soil samples were taken within the study site. The soil sampling sites are correlated with mapping units and represent typical site chemical and physical characteristics. The bedrock material was obtained from drill borings as cores. The deep boring sites were selected on a geological basis, and the drill hole sites became the master sites for characterizing the bedrock material.

After the drill cores were received in the laboratory, they were separated into samples for bedrock evaluation. The basis of separation included geological characteristics and visually observable characteristics (lensing, straining, and cementation). Textural composition (fine, medium, coarse, and others) was also a factor. The majority of the samples are comprised of no more than 5 to 10 feet of the core. A screening technique was used in laboratory characterizations. The following screening tests were run of all samples: electrical conductivity in mmhos/cm and pH (1:5 soil water ration suspensions and 1M $CaCl_2$), settling volume, fragmented hydraulic conductivity, cation-exchance-capacity, total sodium, and percent moisture at 15 bars. Based on the results of the screenable testing program and field observations, additional analyses were made on those samples which appeared to have deficiencies. These included electrical conductivity in mmhos/cm, Na, Ca + Mg, and SAR of the saturation extract, saturation percentage, and exchangeable sodium (ES).

The laboratory results, procedures used, and screenable characterization program are shown in appendix C.

Greenhouse pot studies were made on selected samples to indicate possible toxic or other unfavorable plant growth conditions. Representative core sections were exposed to laboratory freeze-thaw, wetting, and drying cycles to provide an indication of how the geologic material would break down if exposed to the weather. Correlation of these results with actual field conditions is difficult, but they do provide an indication.

The weathering tests and greenhouse studies are presented in appendix C of this report and were considered in evaluating the core material.

Soil Inventory

A composite soil inventory map and descriptions of the various mapping units found in the study site are given in appendix C. The mapping units are essentially soil types with a general range of soil slopes and were obtained from preliminary soil survey data compiled by the Soil Consevation Service.

VEGETATION

Seven vegetative community types are found on the study site: aspen, mountain shrub, sagebrush, and cropland. The sagebrush type is separated into two subtypes: big sagebrush and low sagebrush. The cropland type is separated into three subtypes: winterwheat, hayland, and pasture.

The vegetation is a transition from the higher elevation mountain shrub and aspen community to the lower elevation sagebrush communities.

The vegetation types have been delineated on figure 13 and are described in the following paragraphs. The vegetation types are found on table 8.

Type designations and numbers are those used by the Bureau of Land Management for Automatic Data Processing.

Aspen, Subtype - 101. The aspen (*Populus tremuloides*) community is located on the north-facing slopes in areas with the best soil moisture conditions interspersed within elements of the mountain shrub community. The aspen occurs as an open to dense stand at an average of 43.3 percent aerial cover. When the aspen is a fairly open stand, elements of the mountain shrub community are associated with the understory. Here western serviceberry (*Amelanchier alnifolia*), chokecherry (*Prunus virginiana*) and snowberry (*Symphoricarpos oreophilus*) are found.

This community supports a rich variety of grasses and forbs, including smooth brome (*Bromus inermis*), Kentucky bluegrass (*Poa pratensis*), mountain brome (*Bromus marginatus*), giant hyssop (*Agastache urticifolia*), meadow rue (*Thalictrum fendleri*) and western yarrow (*Achillea millifolium*).

Mountain Shrub, Subtype - 059. The mountain shrub community is found on the north-facing slopes and south-facing rock outcrops of the area, depending on soil depth, texture and available moisture.

This type supports many important browse species, including serviceberry, snowberry and chokecherry. Other associated shrubs are big sagebrush (*Artemisia tridentata*) and green rabbitbrush (*Chrysothamnus viscidiflorus*). Associated grasses and forbs in this type include Kentucky bluegrass, smooth brome, giant wildrye (*Elymus cinereus*), sticky geranium (*Geranium viscosissimum*) western yarow and lupine (*Lupinus argenteus*).

Big Sagebrush, Subtype - 041. The big sagebrush community occurs below the elevational range of the mountain shrub community on deep, well drained fine sandy loam soils. In some areas this community is in the relatively productive soils found in the croplands, but the slopes are too steep for cultivation. This community is used primarily for grazing.

The dominant shrub, big sagebrush, is associated with scattered snowberry, bitterbrush (*Purshia cristata*), Kentucky bluegrass, lupine, penstemon (*Penstemon* spp.) and gromwell (*Lithospermum incisum*).

Low Sagebrush, Subtype - 042. The low sagebrush community occurs below the elevational range of the mountain shrub community, adjacent Fish Creek, on the deep, well drained silty clay loam soils.

The dominant shrub, low sagebrush (*Artemisia arbuscula*) is associated with green rabbitbrush and big sagebrush.

Associated grasses and forbs include Junegrass, western wheatgrass (*Agropyron smithii*), needle and thread, fleabane (*Erigeron* spp.) and lupine. Due to the drought situation at the time of the vegetation survey, understory vegetation was very sparse.

Cropland (Winterwheat), Subtype - 191-A. Winterwheat (*Triticum aestivum*) croplands of the area are on fine sandy loams and loams formerly under the sagebrush community. Approximately half of the cropland is in summer fallow while the remaining is under cultivation.

Associated grasses and forbs in the area, primarily in the fallowed areas, include oats (*Avena sativa*), rye (*Secale cereale*), smooth brome, penneycress (*Thlaspi arvense*), thistle (*Cirsium* spp.) and sunflower (*Helianthus annuus*).

Hayland, Subtype - 191-B. The hayland is located on the same soils as the winterwheat croplands, but on flatter, more productive sites where, in some areas, there is a possibility for subirrigation.

The primary species seeded in the haylands are smooth brome and alfalfa (*Medicago sativa*). Other associated grasses and forbs include mountain brome, Kentucky bluegrass, penneycress, lupine, thistle and dandelion (*Taraxicum officinale*).

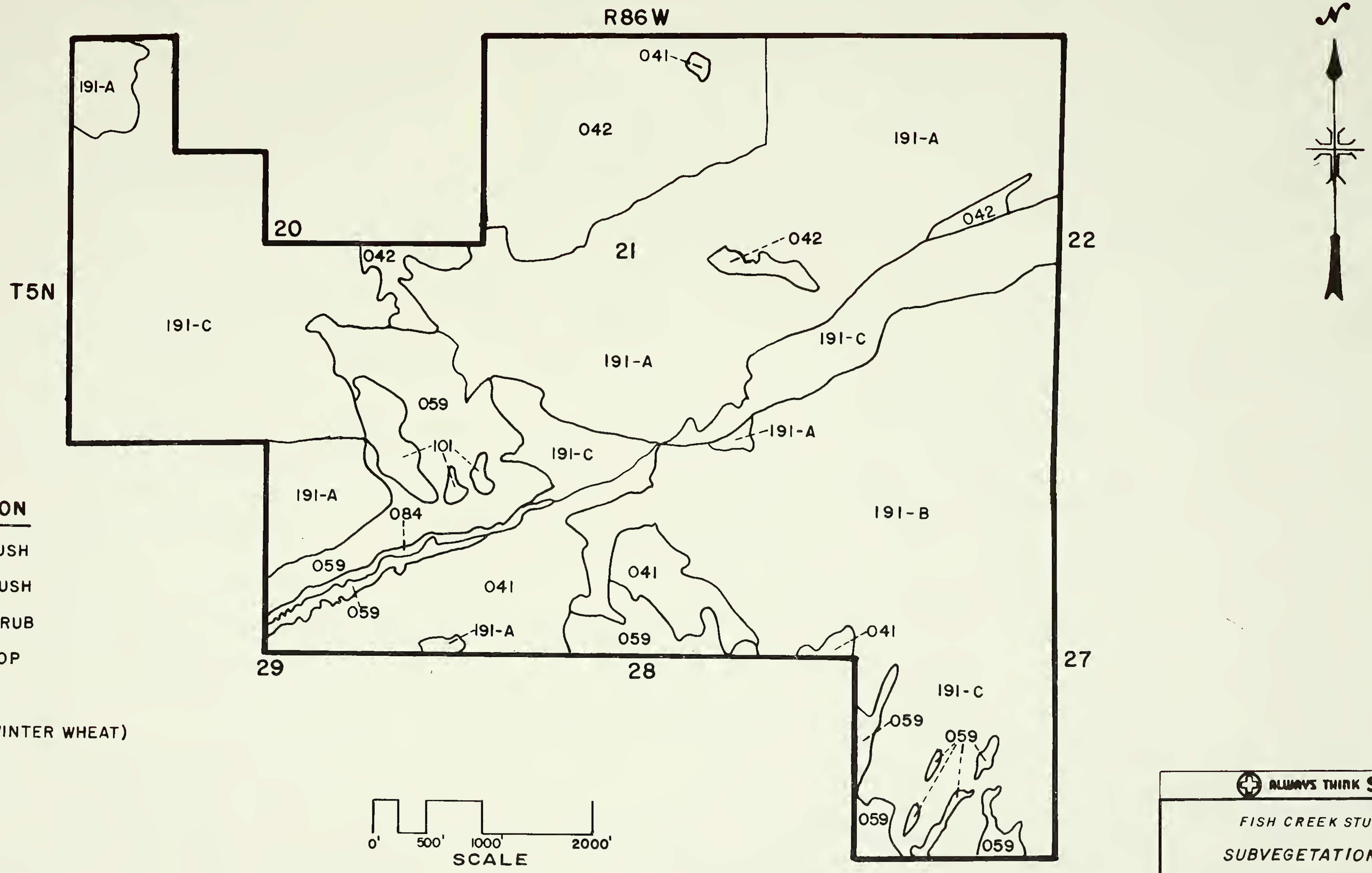
Pasture, Subtype - 191-C. The pasture is located on the same soils as the wheatland and hayland on productive sites where the predominant grass, smooth brome, has been seeded. Productivity is too low, or the terrain is too rough for haying.

Shrubs occurring in the pasture include big sagebrush, green rabbitbrush, and sagewort (*Artemisia dracunculus*).

Associated grasses and forbs include western wheatgrass, Kentucky bluegrass, alfalfa, thistle, dandelion, and salsify (*Tragopogon dubius*).

HYDROLOGY

To assess potential effects of mining on local water resources, an understanding of the hydrology of the Fish Creek study site is needed. This report describes the hydrology of the area after 2 to 18 years of data collection in the area. The report is only the first phase of a continuing study and date-collection effort in this area of Colorado.



LEGEND

SYMBOL	VEGETATION
041	BIG SAGEBRUSH
042	LOW SAGEBRUSH
059	MOUNTAIN SHRUB
084	ROCK OUTCROP
101	ASPEN
191-A	CROPLAND (WINTER WHEAT)
191-B	HAYLAND
191-C	PASTURE

ALWAYS THINK **SAFETY**

FISH CREEK STUDY SITE

SUBVEGETATION TYPES

DESIGNED B.L.M. FIELD APPROVAL
DRAWN TECHNICAL APPROVAL
CHECKED APPROVED

DENVER, COLORADO FIGURE 13

PERCENTAGE AERIAL COVER, MULCH, AND BARE SOIL OR ROCK FOR THE VEGETATION TYPES ON THE FISH CREEK STUDY SITE 1/

Species		Vegetation Types Big sagebrush 041	Low sagebrush 042	Mountain shrub 059	Aspen 101	Cropland (winterwheat) 191-A	Hayland 191-B	Pasture 191-C
Grasses								
Secale cereale	Rye					11.0		
Sitanion hystrix	Squirreltail	2.7						
Stipa comata	Needle and thread	9.7	1.3					
Stipa viridula	Green needlegrass	2.0		0.3	0.3			
Triticum aestivum	Wheat					29.3		
Forbs								
Achillea millefolium	Western yarrow			1.5	1.8	0.3	0.4	0.3
Agastache urticifolia	Giant hyssop				3.0			
Astragalus spp.	Milkvetch							1.0
Cirsium spp.	Thistle			0.8	0.7	0.5	1.3	1.7
Delphinium occidentale	Duncecap larkspur	0.2			1.3			
Equisetum spp.	Horsetail							0.6
Erigeron spp.	Fleabane	0.5	0.5	0.8				
Erigeron speciosus	Showy daisy			0.8				
Geranium viscosissimum	Sticky geranium			1.7	0.5			
Gilia aggregata	Scarlet Gilia	0.7						
Helianthus annuus	Sunflower					0.4		
Lithospermum incisum	Gromwell	1.8		1.7				
Lupinus argenteus	Lupine	2.2	0.5	1.7			1.1	0.6
Medicago sativa	Alfalfa					0.3	41.8	2.7
Melilotus officinalis	Yellow sweetclover							0.2
Penstemon spp.	Penstemon	1.5						
Smilacina racemosa	False soloman's seal				0.2			
Taraxicum officinale	Dandelion					0.2	0.8	2.0
Thalictrum fendleri	Meadow rye				2.5			
Thlaspi arvense	Penny cress			0.5	1.2	1.9	0.6	0.1
Tragopogon dubius	Salsify					0.2	0.2	1.6
Vicia americana	American vetch			1.7	1.5			0.5
Penstemon spp.	Penstemon	1.5						
Bare		5.7	17.0	2.5	0.0	18.8	12.6	5.6
Mulch		9.8	15.5	8.3	5.2	20.5	8.6	28.9

1/ Each number is the mean value for the transects sampled in each type.

2/ Cover value presented for the Aspen canopy is in addition to all other cover.

TABLE 8
page 1 of 2

PERCENTAGE AERIAL COVER, MULCH, AND BARE SOIL OR ROCK FOR THE VEGETATION TYPES ON THE FISH CREEK STUDY SITE 1/

Species		Vegetation Types Big sagebrush 041	Low sagebrush 042	Mountain shrub 059	Aspen 101	Cropland (winterwheat) 191-A	Hayland 191-B	Pasture 191-C
Trees								
Populus tremuloides	Aspen			1.7	43.3 2/			
Shrubs								
Amelanchier alnifolia	Serviceberry	2.8		18.3	20.3			
Artemisia arbuscula	Low sagebrush		42.3					0.2
Artemisia cana	Silver sagebrush							1.4
Artemisia dracunculus	Sagewort							1.3
Artemisia tridentata	Big sagebrush	29.8	3.7	14.0				3.9
Chrysothamnus viscidiflorus	Green rabbitbrush	4.7	1.3	5.2				2.1
Prunus virginiana	Chokecherry			4.5	17.0			
Purshia tridentata	Antelope bitterbrush	8.7						
Quercus gambelii	Gambel's oak				1.7			
Ribes aureum	Golden currant				3.0			
Rosa woodsii	Wild rose			0.7	6.3			
Symphocarpos oreophilus	Mountain snowberry	8.3		18.7	7.5			
Grasses								
Agropyron cristatum	Crested wheatgrass							
Agropyron smithii	Western wheatgrass		3.3					2.1
Avena sativa	Oats					10.9		
Bromus inermis	Smooth brome	1.2		4.3	10.8	4.4	28.8	38.9
Bromus marginatus	Mountain brome			0.3	3.0		2.3	
Bromus tectorum	Cheatgrass brome	1.0				0.4		
Elymus cinereus	Great Basin wildrye			0.8				
Elymus glaucus	Blue wildrye				1.5			
Hordeum jubatum	Foxtail barley					0.3		0.7
Koeleria cristata	Junegrass	3.3	12.7					
Phleum pratense	Timothy grass				0.5			0.2
Poa pratensis	Kentucky bluegrass	2.7		8.7	4.5			

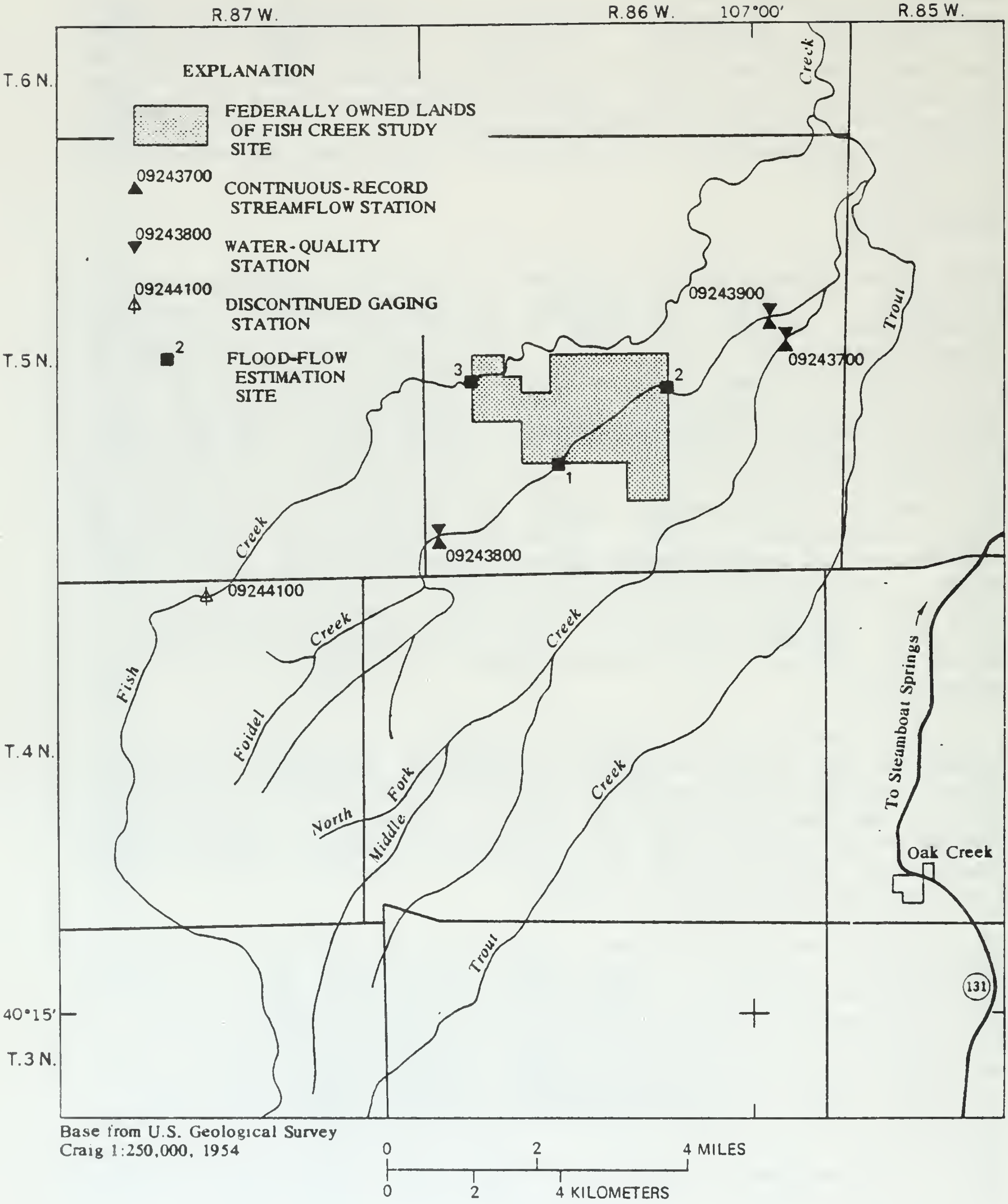
The Fish Creek study site is located in the Foidel Creek and Fish Creek drainage basins. Foidel Creek is tributary to Middle Creek, which flows into Trout Creek; Fish Creek is tributary to Trout Creek. Foidel and Fish Creeks are bounded by Trout Creek to the south and east, Grassey and Sage Creeks to the north, and the Williams Fork River to the west (figure 14). Historical data indicate that the streamflow in the vicinity of the study site is perennial for Fish Creek and intermittent for Foidel Creek.

SURFACE WATER

Three stream gaging stations have been in operation on Foidel Creek and Fish Creek for varying time periods. Two gaging stations in operation since October 1, 1975, are located on Foidel Creek 2.3 mi upstream and 2.3 mi downstream of the study site. The average discharge for 09243800 Foidel Creek near Oak Creek, Colorado, drainage area of 8.61 mi^2, for 0.33 water years 1976-1978 is 0.33 ft^3/s (240 acre-ft/yr). The average discharge for 09243900 Foidel Creek at mouth, near Oak Creek, Colorado, drainage area of 17.5 mi^2, for water years 1976-1978 is 1.21 ft^3/s (876 acre-ft/yr). The 3-year data base is relatively short and may not represent average flow conditions, particularly in light of the drought in 1977. These data indicate that streamflow is intermittent and most discharge occurs from March to June during spring runoff. The average discharge for 09244100 Fish Creek near Milner, Colorado, drainage area of 34.5 mi^2, for water years 1956-1973 is 12.8 ft^3/s (9,265 acre-ft/yr). These data indicate Fish Creek is perennial, although most discharge occurs from March to June during spring runoff.

A flow-duration curve is a cumulative frequency curve that displays the percent of time a given discharge is equaled or exceeded during a given period. The flow-duration curves for the streamflow-gaging stations on Foidel Creek and Fish Creek are shown in figure 15. The Fish Creek flow-duration curve is used to illustrate the use of the curve. A discharge of 34 ft^3/s would be equaled or exceeded 10 percent of the time, based on the 18 years of record.

The shape of the flow-duration curve indicates whether the low flow character of a stream is sustaining or diminishing at the low flow endpoint. The curves for the Foidel Creek stations exhibit diminishing low flow characteristics. That is, the base flow at each station is zero much of the year. The Fish Creek curve indicates flow year-round, reflecting more runoff due to the larger drainage area. The study site is located approximately equidistant between the Foidel Creek stations. Therefore, a flow-duration curve for the study site would plot between the two curves. A flow-duration curve for Fish Creek at the study site would be shifted some unknown amount to the right, reflecting more flow. That is, mean discharge would be equaled or exceeded a greater percent of the time.



Base from U.S. Geological Survey
Craig 1:250,000, 1954

Figure 14. Location of Fish Creek study site.

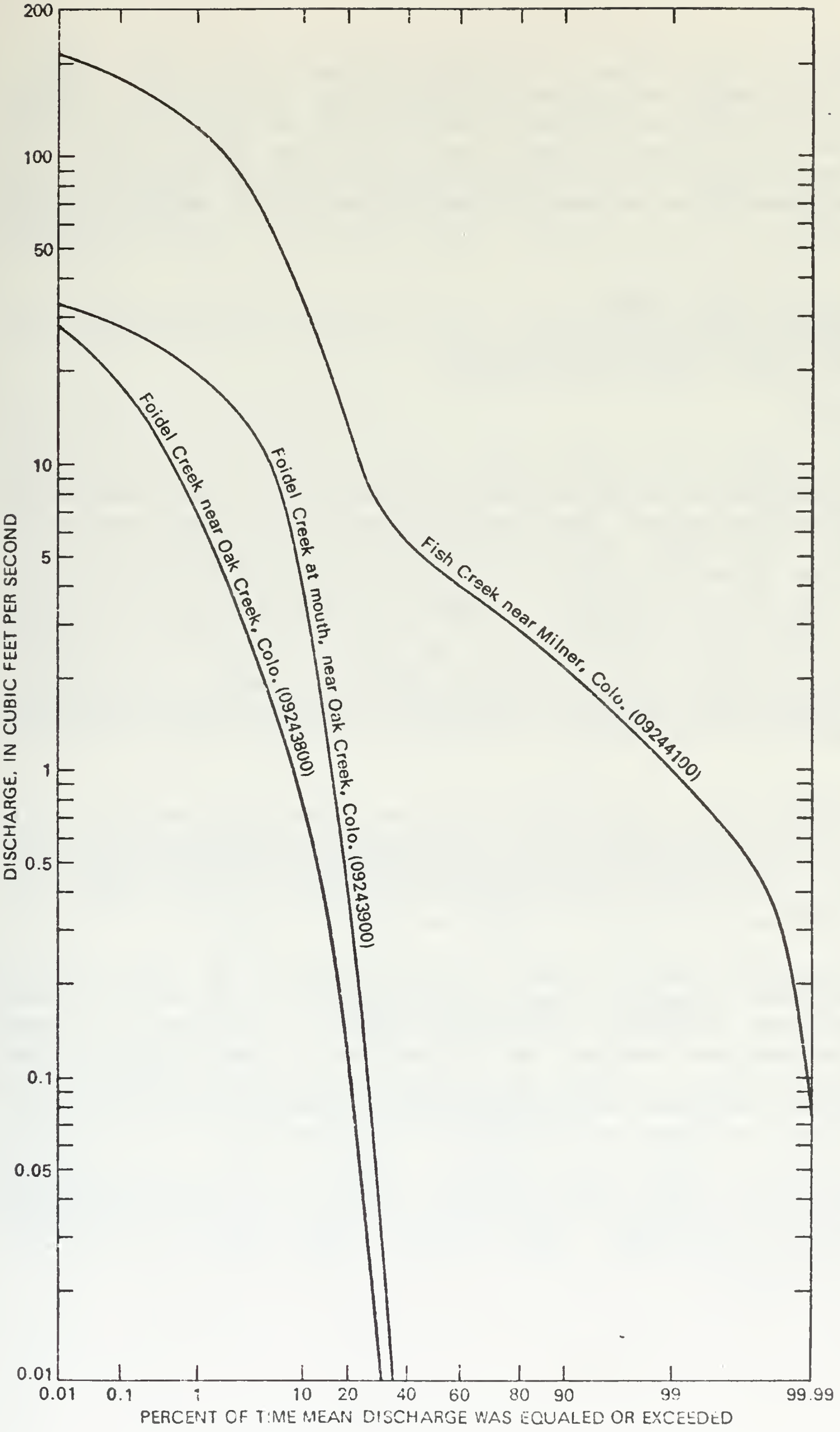


Figure 15. Flow-duration curves of daily mean flow for Foidel and Fish Creeks near Oak Creek and Milner, Colo.

An estimate of flood flows for selected streams in the study site is included to evaluate the potential hazards near the streams. Floods may occur as a result of melting snowpack in the spring, as a result of convective-type cloudburst storms from late spring through fall, or a combination of both. Flood discharges for selected streams in the tract, estimated from the size of the drainage area, the mean annual precipitation, and site elevation (McCain and Jarrett, 1976) are given in table 9.

The potential flood hazards in the study site are minimal, except near the immediate channel, due to the small contributing drainage area which limits the size of the flood discharges.

GROUND WATER

Available ground-water data within the area of study (figure 16) consist of five observation wells which were constructed in 1976, with the assistance of Reclamation. Pertinent construction data for these wells are shown in table 10. Data for observation wells adjacent the study site are not given in table 10. Detailed geochemical data are not available for the study area. However, the Environmental Protection Agency, along with researchers from the Colorado School of Mines' Research Institute, have recently published a report, "Overburden Mineralogy as Related to Ground-Water Chemical Changes in Coal Strip Mining," which lists pertinent geochemical information for the Energy Fuels and Edna Mines that is transferable to the Fish Creek study site.

The Fish Creek study site (figure 14) lies within the Twentymile Park Syncline in the southeastern part of the Yampa coal field. The aquifer units in the area consist of sandstones within the Williams Fork Formation. The Williams Fork Formation ranges from 1,100 to 2,000 ft in thickness and contains the Fish Creek coal bed.

Principal ground-water withdrawal in areas adjacent the study site is mainly from the alluvium or the unconfined part of the Williams Fork Formation. The unconfined part of the aquifer is that which is under atmospheric pressure; whereas the confined part is under greater than atmospheric pressure. There is no continuous boundary between the unconfined and confined parts of the aquifer because of the lenticular nature of the sandstones in the Williams Form Formation.

Within the boundaries of the Fish Creek study site, there is currently no withdrawal from the ground-water system, except by natural discharge of ground water to Foidel Creek and Fish Creek under the prevailing gaining conditions.

Table 9.--Estimated Flood Discharges for Selected Stream Sites

(The estimated flood discharges (Q_2, Q_{10}, Q_{25}, Q_{50}, Q_{100}) are the maximum discharges that should statistically occur for that particular time interval.)

No.[1]	Stream	Flood Discharges, in Cubic Feet Per Second[2]				
		(Q_2,	Q_{10},	Q_{25},	Q_{50},	Q_{100})
1	Foidel Creek at upstream end of study site ----------------------	105	230	20	365	430
2	Foidel Creek at downstream end of study site ----------------------	125	280	30	460	540
3	Fish Creek at study site ----------	230	450	520	670	760

[1] Reference number for flood-flow estimation site shown in table 9.

[2] Flood discharge for indicated recurrence interval (Q_2 refers to the flood discharge that occurs on the average of once every 2 years).

Table 10.--Well Construction Data for Observation Wells Located Within the Fish Creek Study Site

Well location number	Casing I.D., in inches	Well depth	Aquifer	Water level	Date of last measurement
		in feet below land surface			
SB00508621COD-1-----	2	282	Williams Fork Formation	+1.50	7-78
SB00508621AAA-1-----	2	207	----do----	0	7-78
SB00508621BBC-3-----	2	98	----do----	10.70	7-78
SB00508620BCB-1-----	2	30	----do----	13.67	7-78
5800508627BAA-1-----	2	18	Quaternary alluvium	10.39	7-78

Recharge to the rock units within the Fish Creek study site area results from infiltration of precipitation and snowmelt. The amount of recharge is not known, but is probably less than 1 percent of the annual precipitation. There is some recharge to the alluvium during periods of high discharge in Foidel Creek and Fish Creek. This water, however, is immediately released as the stage decreases. Direct recharge to deeper aquifers may occur where streams cross the northwest-southwest trending faults. Small stock ponds within the study site probably do not contribute to recharge because of the high evaporation rates and silting of the pond bottoms.

The altitude of the potentiometric surface is shown in figure 16. Because of well construction methods and well measurement techniques, only a composite surface can be shown. Two of the wells were flowing at the time of the last measurements. Ground-water movement within the study site is shown by the arrows in figure 16. The direction of movement is essentially toward the northeast or towards the axis of the Twentymile Park Syncline. Ground-water movement out of the area is towards the Yampa River. Aquifer tests made on wells outside of the study site show that the rate of movement is very small. Values of hydraulic conductivity range from about 0.1 ft/d to 0.01 ft/d.

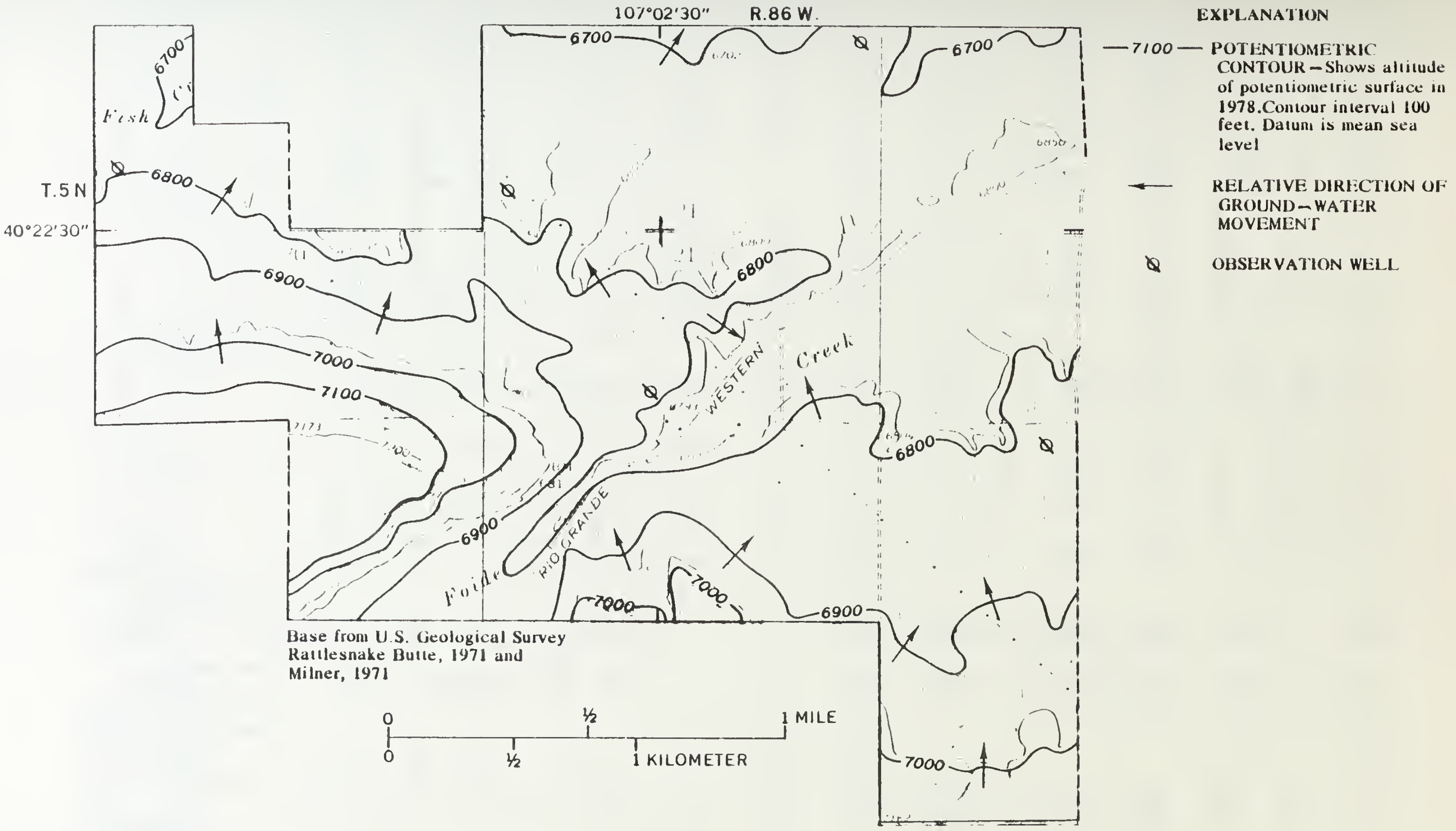
Values for transmissivity usually vary from 5 to 10 ft^2/d. Some transmissivities have been reported to be less than 1 ft^2/d. A discharge of about 10 gal/min for a small diameter well is probably the maximum for wells in this area.

Water Quality

All natural waters contain mineral constituents dissolved from the rocks and soils with which they have been in contact. The concentration of dissolved constituents depends primarily on the type of soil or rock, to some extent the length of contact time, solubility of the minerals, and pressure and temperature conditions. In addition to these natural conditions, man's activities, such as the mining of coal, can have a profound effect on the chemical quality of the water.

All of the data presented in tables 11 and 12 are from the Environmental Protection Agency publication (EPA-600/7-78-156), "Overburden Mineralogy as Related to Ground-Water Chemical Changes in Coal Strip Mining." The location of all cores, ponds, springs, lysimeters, and wells listed in tables 11 and 12 can be found in the above publication.

An interpretation of the data in tables 11 and 12 from Energy Fuels and Edna coal mines shows that the ground water in these adjacent, geologically similar areas can be classified into three major groups: sodium bicarbonate waters, which occur in the lower part of the unconfined zones and in the confined zones; calcium-magnesium sulfate waters, which occur in the thicker shales; and calcium bicarbonate waters, which occur mostly in the alluvium.



107°02'30"
R.86 W.
T.5 N
40°22'30"
Fish Cr
Western Creek
Rio Grande
6700
6800
6900
7000
7100
EXPLANATION
7100 — POTENTIOMETRIC CONTOUR — Shows altitude of potentiometric surface in 1978. Contour interval 100 feet. Datum is mean sea level
RELATIVE DIRECTION OF GROUND — WATER MOVEMENT
OBSERVATION WELL
0
½
1 MILE
0
½
1 KILOMETER

Base from U.S. Geological Survey
Rattlesnake Butte, 1971 and
Milner, 1971

Potentiometric surface and the direction of ground-water movement in the Fish Creek study site.

FIGURE 16

Water data from Energy Fuels Mine, Colo.

[From Hounslow, Fitzpatrick, Cerrillo, and Freeland, 1978, table C-1, p. 222]

Samples	Pond 1	Pond 2	Pond 3	Spoils Flume	Stream	Lysimeter SL-3	Lysimeter SL-4	Well S-6	Well S-9	Well S-10	Well D-6	Well CD-7	Well CD-8	Well D-9	Well D-14
Field Measurements															
Temperature (°C)	13.8	14	17	10.2	14.5	10	4	7.2	10.2	7.2	9.0	6.3	13.7	11.4	8.0
pH	9.2	8.1	6.2	8.4	8.0	7.7	6.5	7.4	7.2	7.6	7.9	10.0	7.7	9.6	6.5
Dissolved O_2 (mg/l)	14	21		16	10	3		14	11	8	14	13	9.1		
Conductivity (µmhos)	450	1,850	2,400	1,750	2,000	2,100	1,700	1,180	1,380	710	800	240	450	780	880
Salinity (°/oo)	0.8	1.8	2.3	1	1.8	2	2	0.5	0.7	0			0	0	1.2
Laboratory Determinations															
Organic															
Total Organic C (ppm)	20.5	3.5	10.9	2.4	14.7	81.2		5.6	6.4	5.9	6.0	4.4	3.0	115	4.8
Phenols (ppm)	<0.003	<0.001	<0.001	<0.001	0.003			0.012	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Tannin + Lignin (ppm)	0.84	<0.05	<0.05	<0.05	0.47			<0.02	<0.05	0.05	<0.005	0.08	<0.05	<0.09	0.09
Physical															
Total Alpha Activity (pCi/l)	6.0±2.7	11±6	24±8	8.7±5.1	19±7			6.4±1.2	6.8±3.9	3.1±1.3	2.0±2.3	2.7±1.1	2.8±1.6		17±5
Total Beta Activity (pCi/l)	0±16	8±19	0±21	0±8.5	5±22			17±10	0±13	0±8	10±6	28±10	0±7.2		38±19
Laboratory Determinations															
Inorganic (mg/l)															
HCO_3^{-1}	141	273	141	296	544	271	219	384	547	571	490	269	312	543	454
Br^{-1}	<0.02	0.25		0.65	<0.02			0.58	16		<0.1	0.26		<0.1	
CO_3^{-2}	53	2	0	0	0	0	0	0		0		5	0	48	0
Cl^{-1}	17	10	10	10	55	59	47	13	16	11	33	32	10	10	18
F^{-1}	1.0	2.1	0.9	0.5	3.2	1.1	0.9	0.7	0.6	0.9	0.46	0.7	0.5	0.2	4.7
$NO_2^{-1} + NO_3^{-1}$	0.2	2.7		1.0	0.5			0.4	0.8	0.3	5.1	0.3	0.7	0.4	<0.1
PO_4^{-3}				<0.1					2.1	<0.1	<0.1	<0.1	<0.1	<0.1	
SO_4^{-2}	68	1,450	1,750	1,440	1,540	1,650	1,450	735	800	176	263	1,393	70	100	500
SiO_2	4.2	6.3	<0.1	0.9	<0.1			9.6	1.9	7.5	11.5	13.3	1.6	85.8	9.6
Al	0.3	0.3	0.3	<1.0	0.3	0.5	0.5	<0.1	<1.0	0.3	<1.0	<0.1	<1.0	<2.0	1.2
As	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.003	<0.005	<0.003	<0.005	<0.005	<0.005	<0.005	<0.005
Ba				<0.2					<0.2		<1.0		<0.2	<1.0	
B	<0.1	<0.1	<0.1	<0.1	<0.1			<0.1	<0.1	<0.1	<0.5	<0.1	<0.1	<0.5	<0.1
Cd	<0.04	<0.03	<0.01	<0.1	<0.04	0.01	0.01	<0.03	<0.1	<0.03		<0.03	<0.1		<0.04
Ca	36	365	429	400	250	407	229	242	153	41	14	28	36	5.4	79
Cr	<0.05	<0.03	<0.05	<0.1	<0.05	<0.005	<0.005	<0.05	<0.1	<0.05	<0.1	<0.05	<0.1	<0.1	<0.05
Co	<0.04	0.06	0.03	<0.1	<0.04	0.03	0.01	<0.04	<0.1	<0.04	<0.04	<0.04	<0.1	<0.04	<0.04
Fe	<0.1	0.3	0.4	0.1	0.1	0.50	0.10	0.2	0.5	0.4	<0.2	<0.1	0.1	1.3	0.7
Pb	<0.03	0.06	<0.01	<0.2	<0.03	0.02	0.09	0.05	<0.2	<0.03	<0.1	<0.03	<0.2	<0.1	0.03
Li				<0.1					0.1		0.1		0.1	<0.1	
Mg	37	127	151	187	229	176	122	105	106	20	8	15	19	1.2	24
Mn	<0.1	<0.1	<0.1	0.1	0.9	3.4	0.05	0.1	0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Hg	<0.0001	0.0001	0.009	0.0001	<0.0001			0.0003	0.0001	<0.0001		0.0001	0.0002		<0.0001
Mo	<0.01	0.02	<0.01	<0.02	0.10			<0.01	0.11	0.02	<0.01	<0.01	<0.02	0.03	0.02
Ni	<0.1	<0.1	<0.1	<0.1	<0.1	0.08	0.10	<0.1	<0.1	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1
K	2.2	2.9	5.2	3.7	2.6	22	6	1.4	3.9	3.3	2.0	25	2.6	2.7	3.0
Se	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Na	33	30	30	38	134	200	371	59	223	200	286	18	108	271	237
Sr	0.3	3.1	4.3	3.5	1.8	5	2	1.4	2.0	0.7	0.6	0.35	1.6	0.1	1.5
Tl	2.09	0.56	0.65	0.53	1.46	0.0	<0.10	0.40	0.23	0.68	0.25	0.22	0.08	0.32	0.44
Zn	<0.1	<0.1	0.04	0.4	0.1	0.48	0.22	0.10	0.4	0.2	0.1	0.1	0.2	0.2	<0.1

TABLE 11

Water data from Edna Mine, Colo.

[From Hounslow, Fitzpatrick, Cerrillo, and Freeland, 1978, table C-2, p. 223]

Samples	Pond 1	Pond 2	Pond 3	Spring 1	Spring 2	Spring 3	Spring 4	Lysimeter SL-3	Lysimeter SL-10	Lysimeter SL-12	Well S-5	Well S-7	Well S-8
Field Measurements													
Temperature (°C)	25	24	16.8	9.8	10.0	10.3	11.5	8.5	12	7	10	8	14
pH	8.2	8.3	7.3	7.2	7.1	7.6	7.4	6.8	6.9	8.4	7.0	7.3	7.1
Dissolved O_2 (mg/l)	9	14		15	17	15	15	4	2	2	3	5	8
Conductivity (μmhos)	2.380	2.170	2.180	1,625	1,640	1.810	2.000	1,940	2,400	4,050	1,220	140	560
Salinity (°/oo)	1	2.1	2.0	1.0	1.0	1.6	1.8	1.5	2	2.5	0.5	0	0
Laboratory Determinations													
Organic													
Total Organic C (ppm)	5.3	4.0	4.1	3.4	2.7	2.8	3.5	9.4	16.7	11.5	3.9	2.2	15.43
Phenols (ppm)	0.004	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001				<0.001	0.008	0.012
Tannin + Lignin (ppm)	<0.02	<0.02	0.05	<0.002	<0.002	<0.02	<0.02				<0.02		
Physical													
Total Alpha Activity (pCi/l)	6.4±4.9	3.1±3.8	11±5	4.5±2.1	4.5±3.5	8.7±5.5	0±3.5				12±4	3.0±1.4	0.4±1.2
Total Beta Activity (pCi/l)	13±22	4±21	26±19	0±16	0±23	0±22	11±22				20±12	0±9	12±10
Laboratory Determinations													
Inorganic (mg/l)													
HCO_3^{-1}	128	53	107	168	247	163	162	137	253	730	410	116	181
Br^{-1}	0.45	<0.02	0.07	0.30	0.36	0.34	0.49	<0.02		<0.02		0.41	
CO_3^{-2}	0	2	0	0	0	0	0	0	0	0	0	0	0
Cl^{-1}	13	14	13	10	10	10	12	11	47	22	14	4	14
F^{-1}	1.2	1.6	2.0	0.6	0.6	1.6	2.2	0.7	0.8	0.8	1.1	1.1	1.2
NO_2^{-1} + NO_3^{-1}	0.4	0.3	<0.1	1.0	0.4	0.4	0.4				0.7	0.4	2.2
PO_4^{-3}				<0.1	<0.1								
SO_4^{-2}	210	1.488	1,250	1,650	1.563	1.563	1,725	1,875	1,634	2,975	775	25	1,530
SiO_2	7.7	0.5	<0.1	0.7	3.7	10.5	10.1				5.8	11.2	5.8
Al	<0.1	0.1	0.1	<0.1	<0.1	0.1	0.1	0.5	0.5	0.5	<0.1	<0.1	<0.1
As	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.003	<0.005
Ba				<0.2	<0.2								
B	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1				<0.1	<0.1	<0.1
Cd	<0.03	<0.03	<0.04	<0.1	<0.1	<0.03	<0.03	0.01	0.01	0.01	<0.03	<0.03	<0.03
Ca	500	386	415	407	415	472	486	440	420	170	276	26	276
Cr	0.14	<0.05	<0.05	<0.1	<0.1	<0.5	<0.05	<0.005	<0.005	<0.005	<0.05	<0.05	<0.05
Cu	<0.04	<0.04	<0.04	<0.1	<0.1	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Fe	0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	12	0.5	6.6	0.2	2.0
Pb	0.07	0.05	0.05	<0.1	<0.1	0.06	0.06	0.05	<0.01	0.20	0.05	<0.03	<0.03
Li				<0.1	<0.1								
Mg	150	113	151	169	150	178	157	182	111	158	92	10.7	29
Mn	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.3	7.5	0.2	0.1	0.2	0.8
Hg	0.0006	0.004	<0.0001	<0.0001	<0.0001	<0.0001	0.0001				<0.0001		0.0007
Mo	<0.01	<0.01	<0.01	<0.01	0,01	<0.01	<0.01				<0.01	<0.01	<0.01
Ni	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.1	0.1	<0.1	<0.1	0.1
K	4.7	2.7	2.6	2.2	2.6	2.2	3.2	4.0	5.0	38	4.0	1.3	6.6
Se	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.008	<0.005	<0.005	<0.005
Na	26	25	22	11.4	13.7	14	25	26	86	1,140	24	4.8	14
Sr	1.9	2.6	2.4	1.6	1.7	2.0	2.6	1.5	2.2	13	3.3	0.1	0.4
Ti	0.34	0.34	0.59	0.05	0.03	0.20	0.23		0.72	0.72	0.30	0.20	0.43
Zn	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	2.3	0.1	0.1	0.1	0.2

The origin of these three water types is given below:

Water Type 1 (Na-HCO_3). The water most nearly representative of this end member is that of Sample D-9 (table 11) which is artesian in origin. The total dissolved solids content of this water type is approximately 600 mg/L. On this basis, the sodium bacarbonate water is unusual. Also it contains considerably less calcium and magnesium than is usually reported as occurring with the sodium. A possible explanation of the bicarbonate ground water is that it results from sulfate reduction. Where water and organic material are in contact, such as in coal seams, this reaction is catalyzed by anaerobic bacteria. The reaction generally proposed is

$$SO = _4 + CH_4HS + HCO - _3 + H_2O \qquad (1)$$

The sulfide produced by this reaction leads to the precipitation of iron and some heavy metals present in the original water.

Further, if calcium and magnesium were initially present in the water, these elements may have been absorbed by montmorillonite clay, releasing sodium into solution.

Water Type 2 (Ca-Mg-SO_4). The samples representative of this water type are the four springs and three ponds from the Edna Mine (table 12), and two ponds from the Energy Fuels Mine (table 11). The water in these ponds either moved through the spoils material prior to emerging at the surface, or was otherwise in direct contact with spoils material.

Possible mechanisms for the production of Water Type 2 chemistry include the following:

1. Leaching of the gypsum and starkeyite from the spoils piles. This would be the most likely mechanism, assuming sufficient gypsum in the spoils.

2. Bacterial or chemical decomposition of pyrite to sulfuric acid coupled with the solution of calcite and dolomite. This, again, is dependent upon the presence of pyrite.

3. Bacterial oxidation of the organic sulfur in the coal and the reaction of the sulfuric acid so formed with calcite and dolomite.

The coal does contain about 0.5 percent organic sulfur, and the near-neutral pH is optimal for most sulfur bacteria. The questionable points are:

1. whether sufficient coal remains in the spoils to account for the sulfate content of the water; and

2. whether sulfur-oxidizing bacterial are present.

Water Type 3 (Ca-HCO3 low total dissolved solids). The water most representative of this type is that of Sample S-7 (table 12) from the Edna Mine, which is water from the shallow alluvial aquifer.

Four ground-water analyses are plotted on figure 17. Based on geology and well depth the three-phase system is quite apparent. Depending upon the geology of the overburden, calcium and magnesium concentrations may not be critical. More detailed sampling will be necessary to map the chemical facies present in the study site.

A measure of the dissolved constituents in the surface water is expressed in terms of specific conductance. The relationship between water discharge and specific conductance is shown (figures 18, 19, and 20) for the three water-quality stations identified in figure 13. The method of least squares was used to obtain a statistical relation between these two variables. Note that the exponents in each equation, shown in figures 18-20, are very small. Therefore, from the results obtained from this data thus far, it appears that very little dilution occurs in the dissolved solids as discharge increases.

The primary constituents in the dissolved system at these three gaging stations are calcium, magnesium, bicarbonate, and sulfate. These major constituents for each of the gaging stations are shown in figures 21-23. These constituents are plotted against specific conductance so that the relative magnitude of each constituent can be determined for a range of dissolved solids. Because the ratio of dissolved calcium to magnesium averages 2.3, only the values of dissolved calcium are plotted.

The relations between specific conductance and these major constituents were obtained by the method of least squares and are given in table 13. Samples collected from Foidel Creek near Oak Creek from March 1976 through June 1978 were analyzed for major ions and selected tract constituents (appendix D). Results of these analyses can be used to characterize the dissolved solids in the samples and estimate the contraints that may exist for minor or trace components. Table 14 lists the mean concentrations and standard deviations of the major ion analyses. The average concentrations listed in table 14 meet promulgated standards for both aquatic life and domestic drinking water supplies (Environmental Protection Agency, 1976).

In addition to a comparison of analytical results with promulgated standards, the likelihood of sporadic high concentrations can be assessed by consideration of solubility limitations for many chemical constituents. For example, table 15 lists the logarithm (base 10) of the activity product divided by the solubility product for the analyses considered here. The Log_{10} of this ratio is a measure of the tendency of a mineral to dissolve into the solution of precipitate from it; positive values denote a tendency to precipitate from solution, while negative values denote a tendency to dissolve into solution, thereby increasing the concentrations of the appropriate ions in solution. For a detailed discussion of activity products and solubility products see Garrels and Christ (1965). The data in table 15 were calculated from

Well number	Well depth (ft)	As (UG/L	Dissolved Fe (UG/L)	Mn (UG/L)	pH	Se (UG/L)	Specific conductance (µmhos/cm)	Dissolved Zn (UG/L)
FM-3	122	--	20	10	8.7	0	900	10
BR-5	173	--	1,200	60	7.4	0	1,300	60
BR-10	198	0	250	20	8.1	0	3,400	--
BR-8	18	1	30	15	7.2	2	610	--

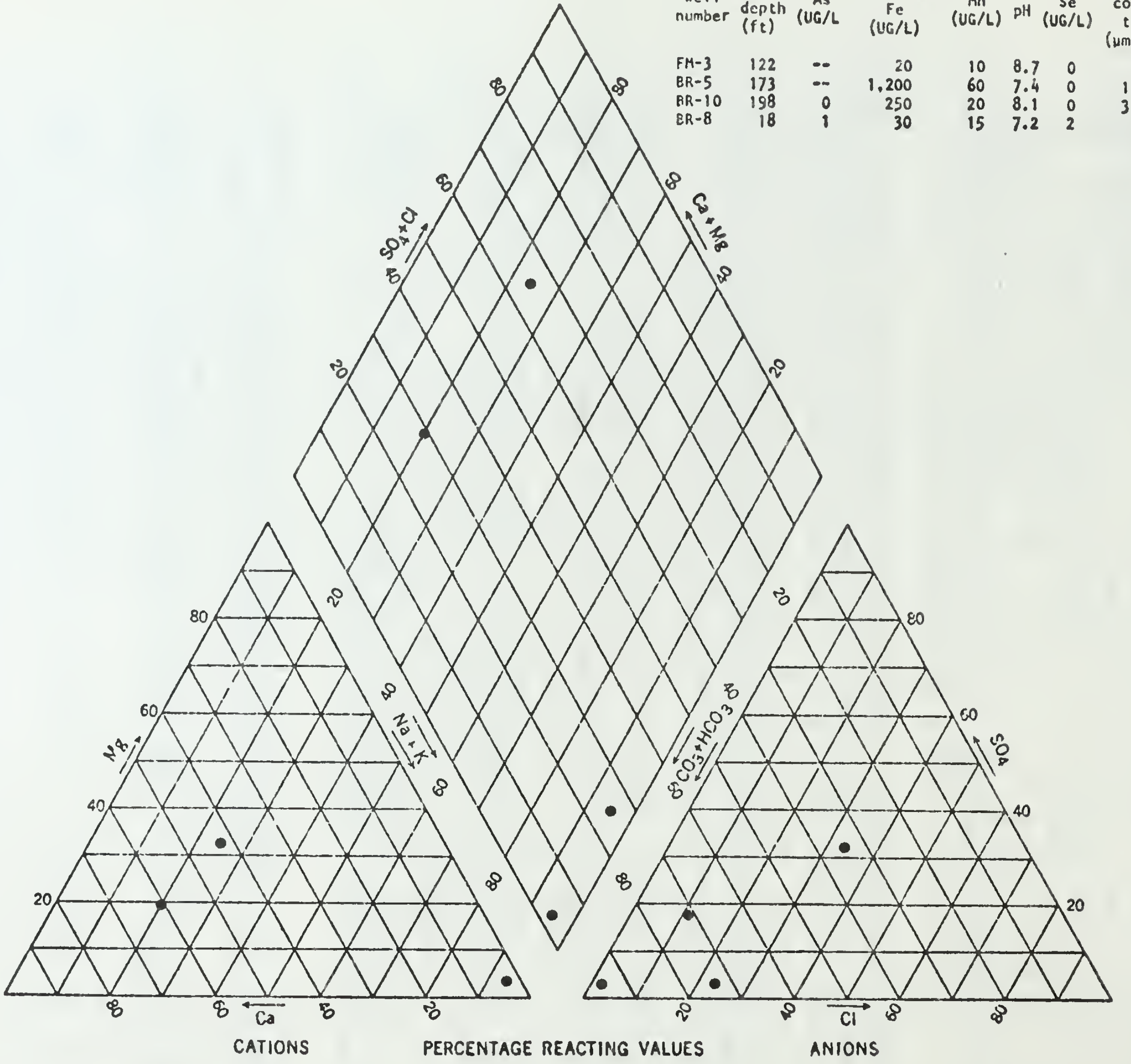


FIGURE 17

Water-analysis diagram showing ground-water variation in wells adjacent to the Fish Creek study site, Colo.

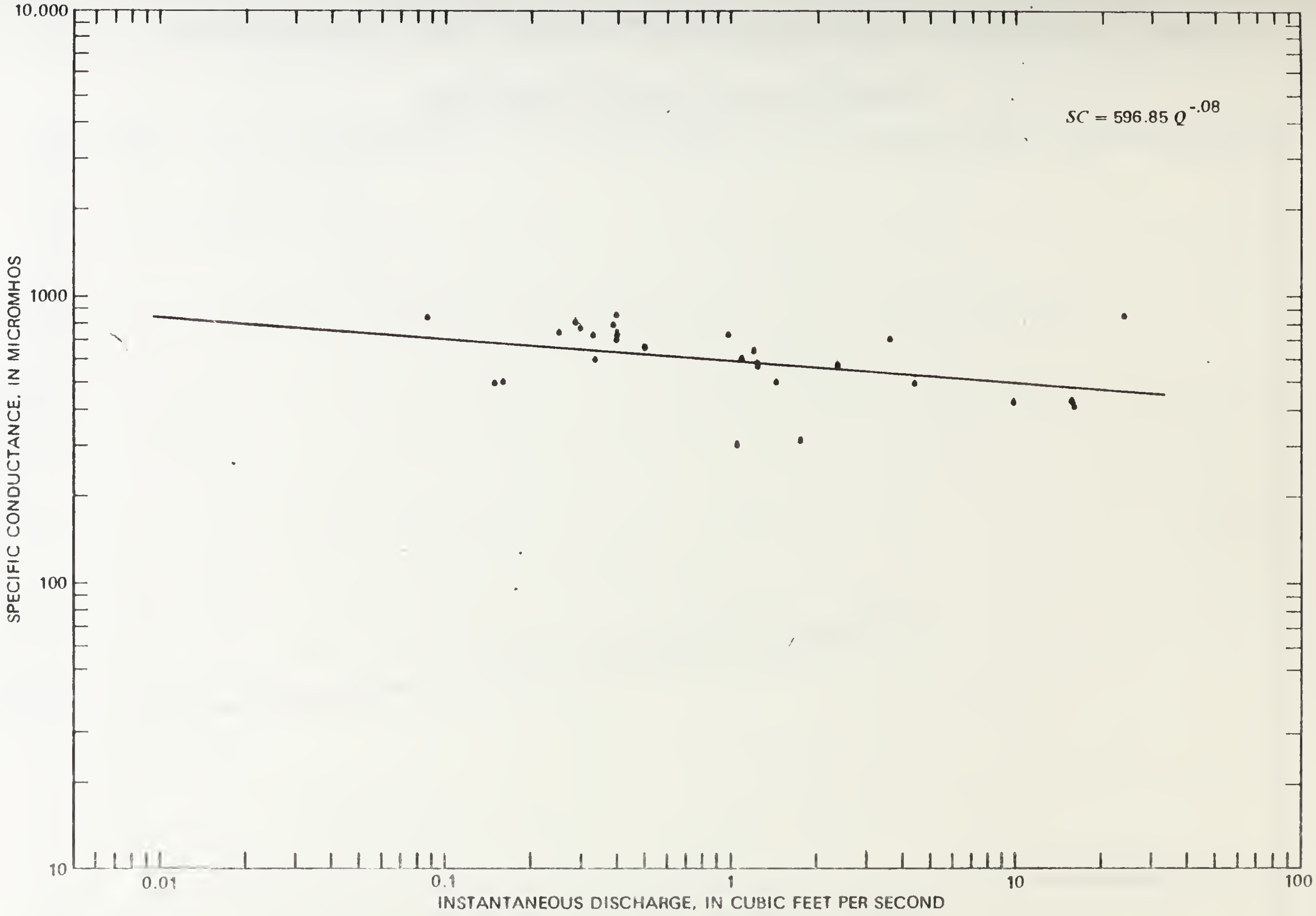
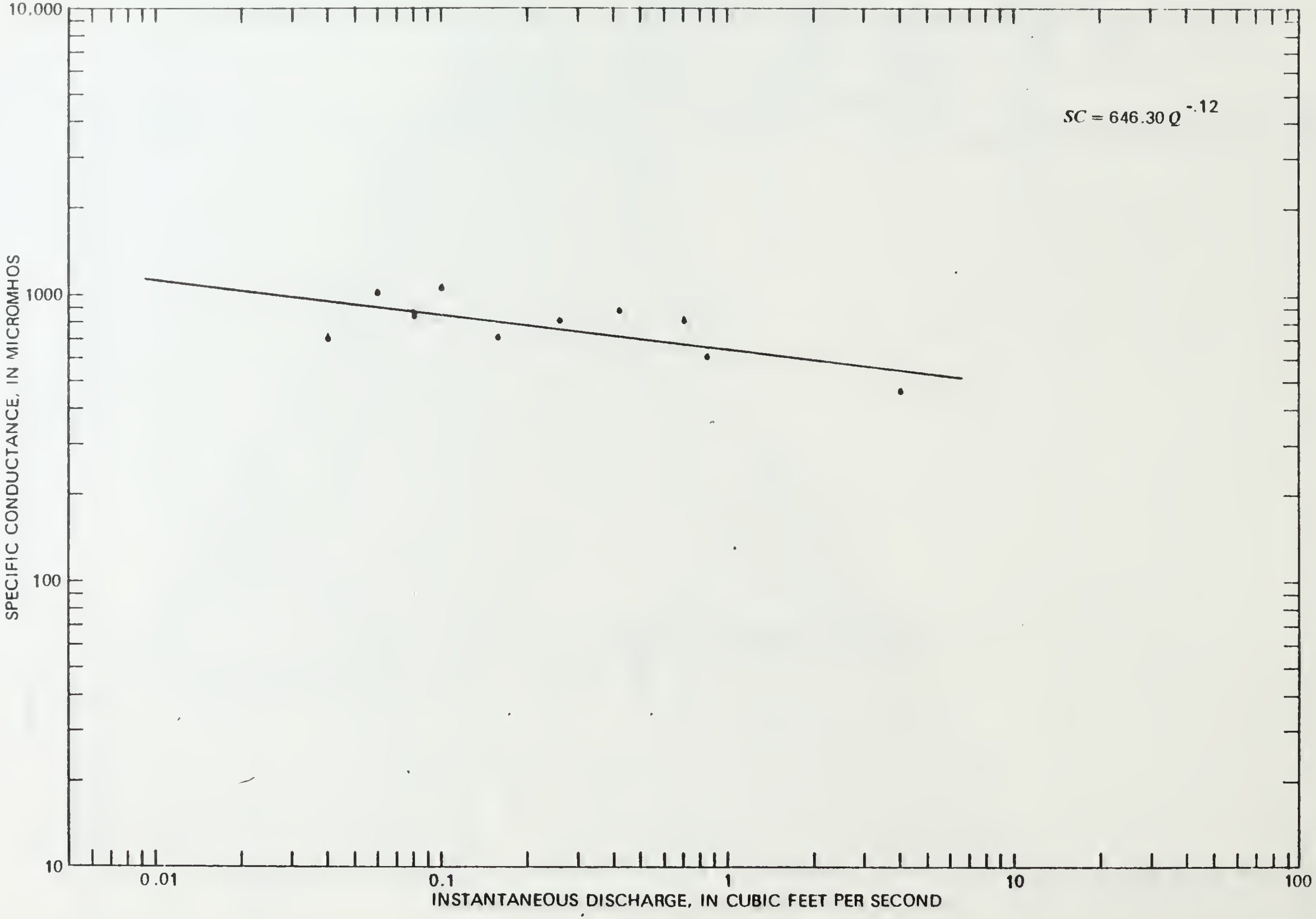


FIGURE 18

Instantaneous discharge versus specific conductance for Middle Creek near Oak Creek, Colo. (09243700).



Instantaneous discharge versus specific conductance for Foidel Creek near Oak Creek, Colo. (09243800).

FIGURE 19

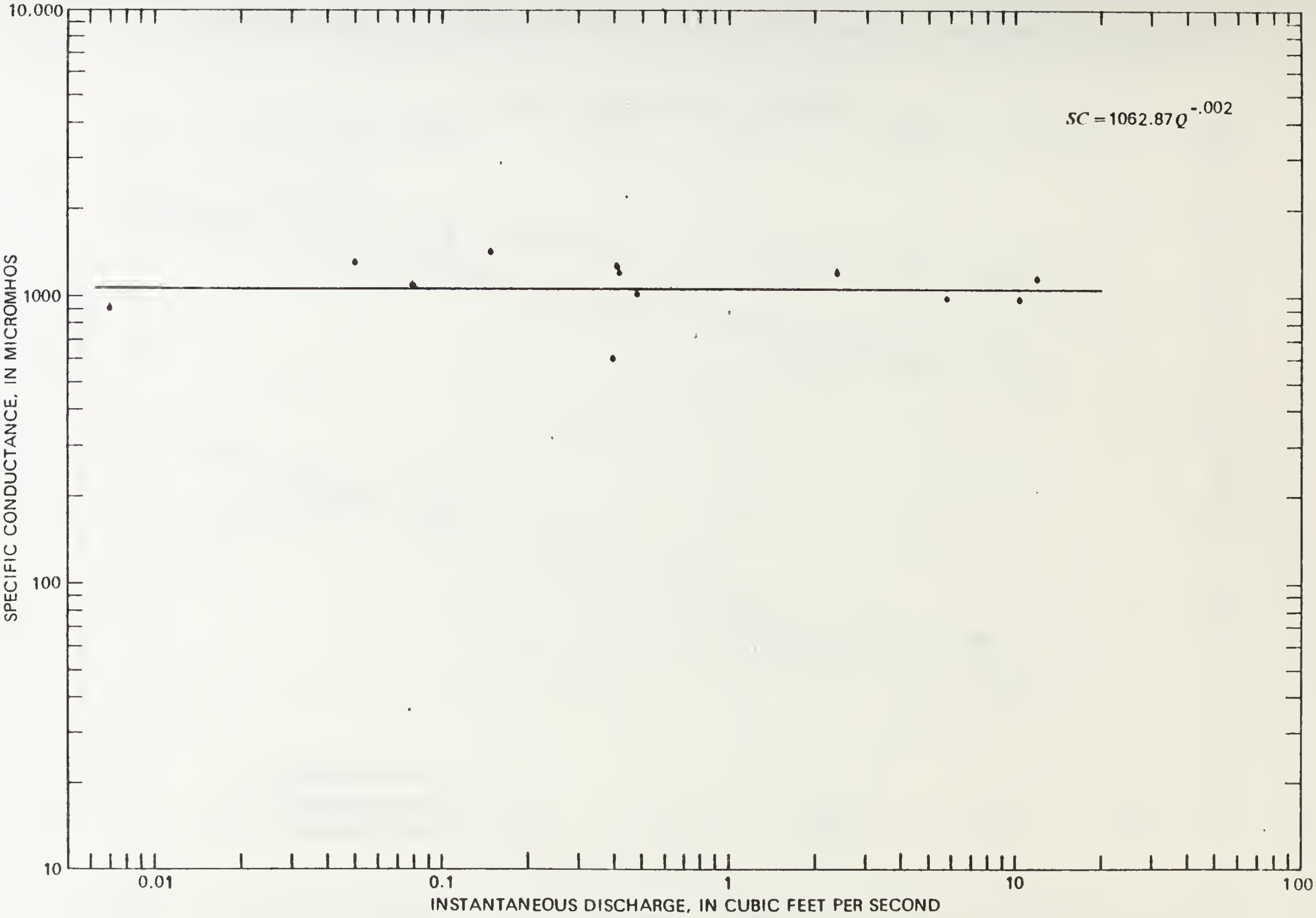
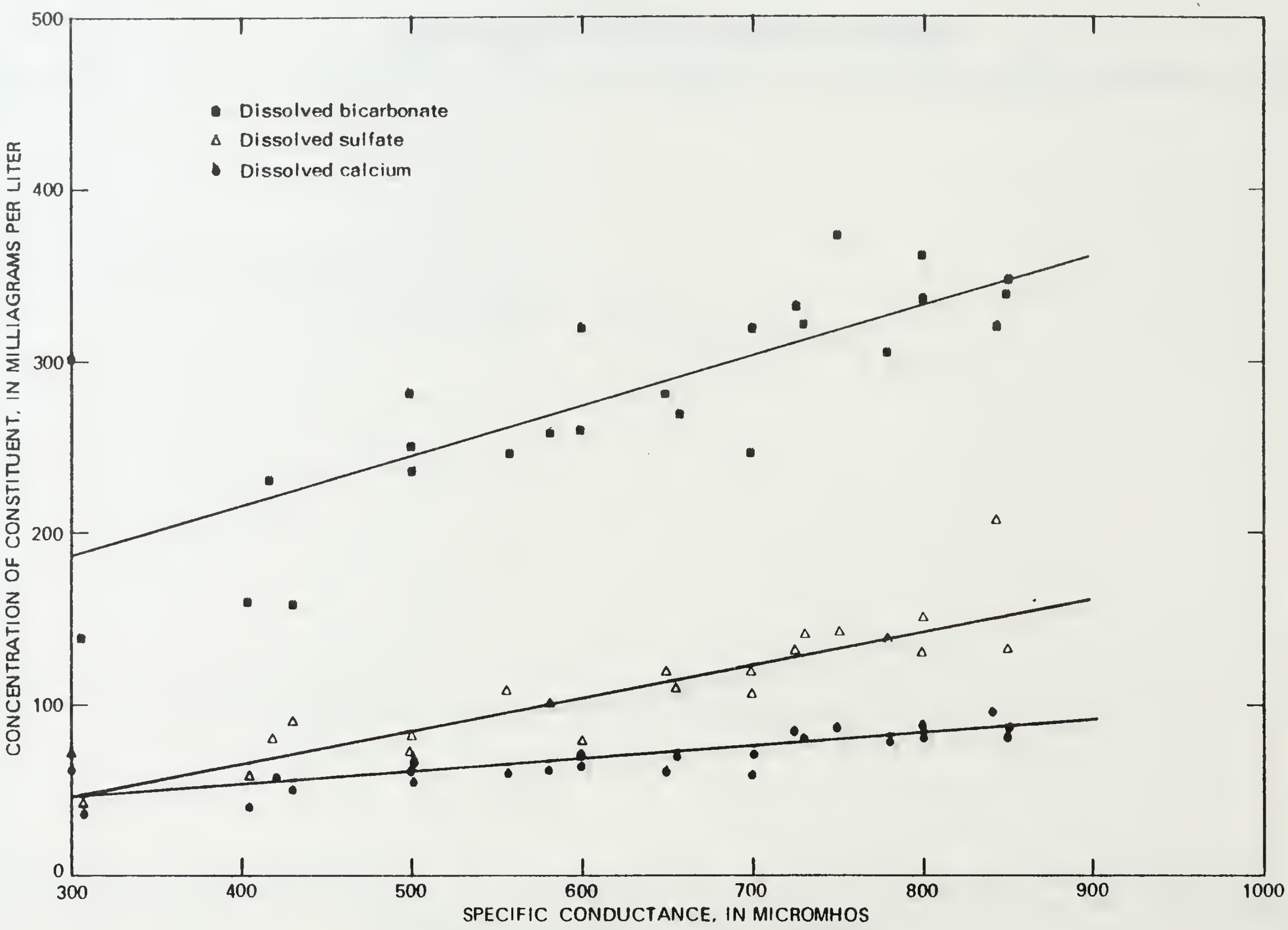


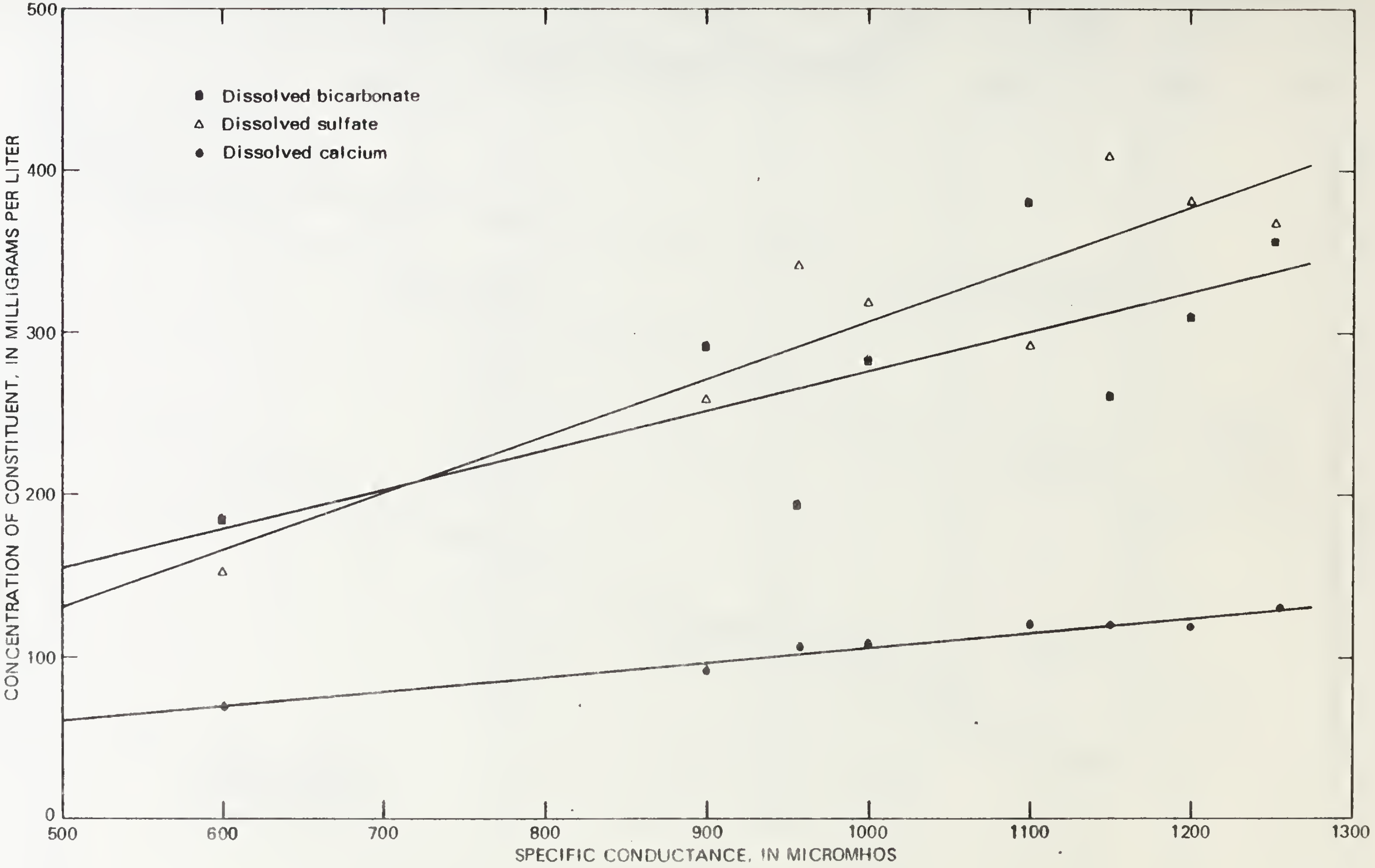
FIGURE 20

Instantaneous discharge versus specific conductance for Foidel Creek at mouth, near Oak Creek, Colo. (09243900).



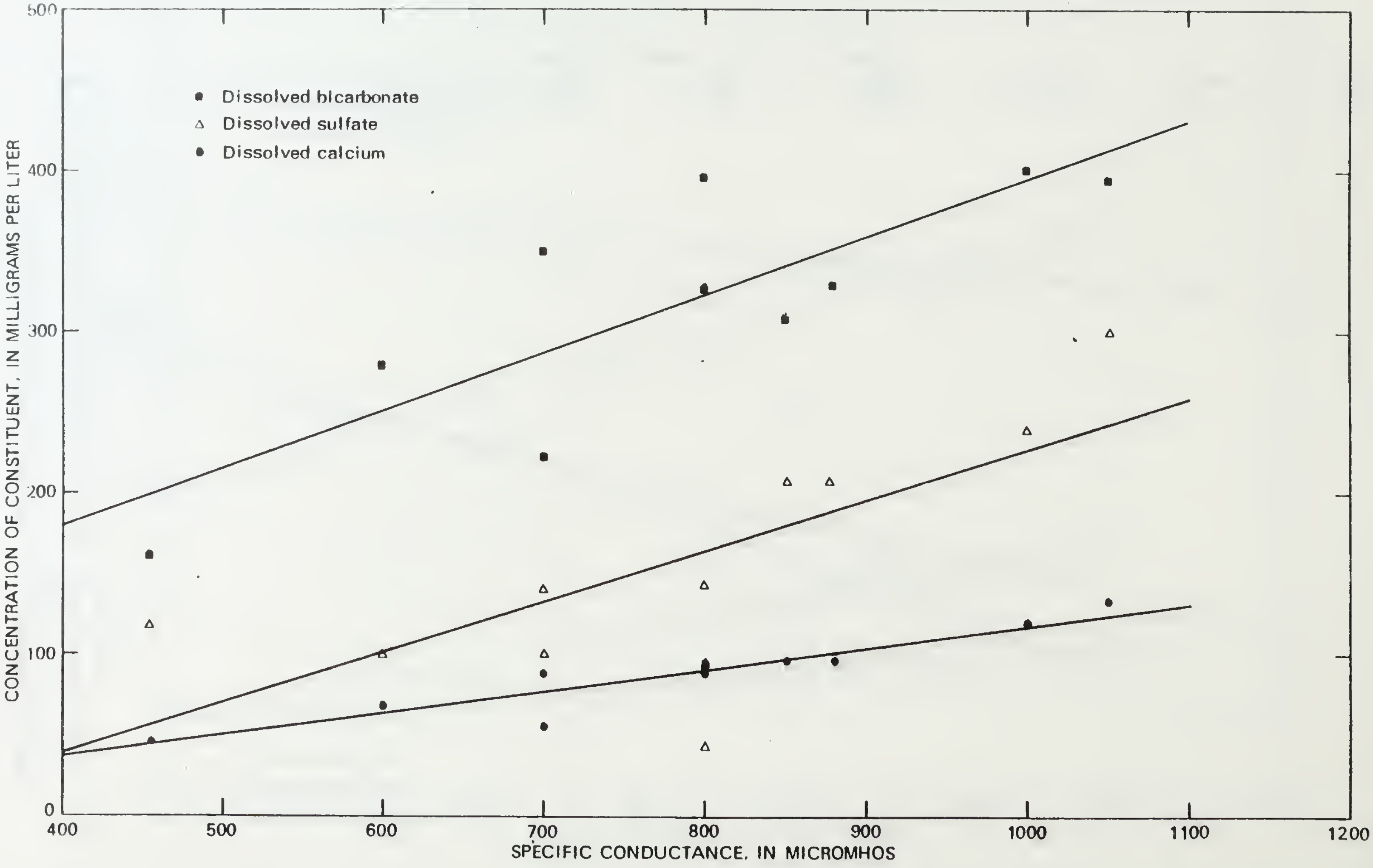
Major constituents versus specific conductance for Middle Creek near Oak Creek, Colo. (09243700).

FIGURE 21



Major constituents versus specific conductance for Foidel Creek near Oak Creek, Colo. (09243800).

FIGURE 22



Major constituents versus specific conductance for Foidel Creek at mouth, near Oak Creek, Colo. (09243900).

FIGURE 23

Table 13.--Least-squares Equations for Major Constituents Versus Specific Conductance for the Three Water-quality Stations

Constituent	n	r^2	Standard error of estimate	Equation
09243700 Middle Creek near Oak Creek, Colorado				
Calcium (mg/L)....	25	0.72	7.46	$C_{Ca} = 25.49 + 0.069SC$
Bicarbonate.......	25	.61	39.49	$C_{HCO_3} = 99.69 + 0.289SC$
Sulfate...........	24	.72	19.97	$C_{SO_4} = -5.49 + 0.186SC$
09243800 Foidel Creek near Oak Creek, Colorado				
Calcium (mg/L)....	10	0.92	7.21	$C_{Ca} = -16.2 + 0.123SC$
Bicarbonate.......	10	.67	47.50	$C_{HCO_3} = 36.6 + 0.36\ SC$
Sulfate...........	10	.54	55.22	$C_{SO_4} = -90.3 + 0.32\ SC$
09243900 Foidel Creek at mouth, near Oak Creek, Colorado				
Calcium (mg/L)....	8	0.95	4.93	$C_{Ca} = 15.2 + 0.09\ SC$
Bicarbonate.......	8	.53	52.50	$C_{HCO_3} = 32.8 + 0.24\ SC$
Sulfate...........	8	.81	38.40	$C_{SO_4} = -48.1 + 0.356SC$

Table 14.--Mean Concentration and Standard Deviations of the Concentration of Major Ions in Samples From Foidel Creek Near Oak Creek

(In milligrams per liter)

Ion	Mean	Standard deviation
Calcium..........	89	7.2
Magnesium........	40	3.3
Sodium...........	27	3.3
Potassium........	3.4	.4
Bicarbonate......	316	48
Sulfate..........	161	55
Chloride.........	5.2	.9

the data in appendix D by use of the computer program SOLMNEE (Kharaka and Barnes, 1973). The data in table 15 indicate that the minerals calcite, dolomite, and magnesite ranged from supersaturated to undersaturated.

Table 15.--The Logarithm (Base 10) of the Activity-product to Solubility-product Ratio with Respect to Selected Minerals for Samples from Foidel Creek near Oak Creek

Sample date	Ratio, in dimensionless units Calcite	Dolomite	Magnesite
76/03/05...	0.23	0.50	-0.39
76/04/08...	-.02	.03	-.61
76/05/07...	.34	.76	-.22
76/06/04...	.24	.59	-.28
77/03/18...	-.19	-.37	-.84
77/04/14...	-.31	-.58	-.92
77/05/11...	-.23	-.43	-.84
78/04/18...	.21	.54	-.31
78/05/30...	.74	1.61	.26
78/06/19...	.68	1.49	.19

A likely explanation for this indicated change in water quality is that the ground water which seeps into Foidel Creek is approximately saturated with calcite, dolomite, and, perhaps, magnesite. Dilution by snowmelt causes the system to become undersaturated, while concentration by evaporation causes supersaturation. If the ground-water input to Foidel Creek is saturated with calcite and dolomite because of its contact with the country rock of the area, then the major ion chemistry of Foidel Creek will respond primarily to dilution and evaporation in the absence of direct input by man. Thus, concentrations of the major ions can be expected to approximate the ranges of concentration shown in appendix A.

The capability of water from Foidel Creek reacting with dissolved trace metals and precipitating out these trace metals can be evaluated for selected trace metals and appropriate minerals. For example, in an oxidizing environment such as a surface-water stream, the solubility of iron can be expressed by equation (2) (Garrels and Christ, 1965, p. 185):

$$\mathrm{Log}_{10}(\mathrm{Fe}^{+3}) = -0.72 - 3\mathrm{pH}. \qquad (2)$$

In equation (2), Log_{10} denotes the logarithm base 10, (Fe^{+3}) denotes the activity of the ferric ion considered equal to the concentration in moles per liter, and pH denotes the solution pH. At a pH of 7.1, the lowest shown in appendix D, the solubility of ferric ion is only $10^{-22.0}$ moles per liter, or much less than a microgram per liter.

The solubility of some carbonates is sufficiently low to allow effective controls on the solubility of some trace metals. For example, equation 3 considers the solubility of lead carbonate, at 25 C:

$$\mathrm{Log}_{10}\,(\mathrm{Pb}^{+2}) = 13.45 - \mathrm{Log}_{10}\,(\mathrm{CO}^{=3}) \qquad (3)$$

In equation (3), Pb^{+2} denotes divalent lead ion and $\mathrm{CO}^{=3}$ denotes carbonation. Using data from appendix D, the carbonate ion activity can be shown to range from $10^{-4.6}$ to $10^{-5.7}$. The corresponding maximum solubility of divalent lead is 0.3 and 4 ug/L, respectively. Similar calculations for the zinc and copper carbonates show zinc solubility to range from 490 to 6,200, and copper solubility to range from 640 to 8,060 g/L, respectively.

In summary, the major ion chemistry of Foidel Creek probably results from equilibration of ground-water seepage with calcite and dolomite, followed by varying degrees of dilution or concentration by evaporation. The carbonate ion resulting from this contact with carbonate rocks may limit soluble lead concentrations to a few micrograms per liter. The concentration of soluble copper and zinc, however, may range up to several thousand micrograms per liter if carbonate solubility is the only control. Dissolved iron concentrations will probably not be a long-lived problem in the oxidizing environment of the stream because of the small solubility of the ferric ion at the pH values encountered in this stream.

EFFECTS OF MINING ON AREA HYDROLOGY

The majority of annual runoff originates in the form of snow melt during the spring months, as reflected in the streamflow records for Foidel and Fish Creeks. As the streamflow records are of short duration and were not collected at the proposed site, the effects of mining on the hydrology can only be presented in relative terms.

The effects of mining on the quantity of runoff differs for each stream in the proposed study area because of the size of the drainage area and the location of each stream channel through the study site. The study site consists of 3.4 mi^2; of that, 1.8 mi^2 drains into Foidel Creek and 1.6 mi^2 drains into Fish Creek. The total drainage at the upstream end of the study site for Foidel and Fish Creeks is 12.3 mi^2 and 51.4 mi^2, respectively. As the contributing area from the study site is relatively small to the total drainage area, the effects upon streamflow should be minimal. As the two stream-gaging stations on Foidel Creek bound the study site, effects from mining activities could be properly assessed.

Suspended-sediment concentrations have been sampled periodically at the three water quality stations since 1975. Concentrations range from 16 to 75 mg/L. This larger concentration was obtained at a discharge of 16 ft^3/s, which yields an instantaneous suspended-sediment discharge of 32 tons/day.

It must be pointed out that sufficient sampling at the higher discharges and correlation with the automatic pumping sampler has not yet been done. Thus, the range of suspended sediment could be considerably higher.

The bed and banks of the Foidel Creek and Fish Creek channels consist primarily of silts and clays, and the valleys in which these streams flow consist primarily of fine-grain material. Disruptions near the channel could, therefore, increase suspended-sediment concentrations dramatically. Once in suspension, this fine-grain material could travel great distances downstream.

Whether the mining activities would increase or decrease, flow would be determined by the extent and practices at the mining tract. If there are no water-conveyance channels in the mined area, the snowmelt would probably infiltrate into the ground and decrease the amount of surface runoff or change the time distribution of the surface runoff. As pointed out previously, disruptions of the alluvium or the channel proper could increase suspended-sediment concentrations. This fine-grained material could travel great distances downstream. If some buffer between the mine proper and the channel is established, little increase in suspended sediment should be noted.

Qualitative estimates of channel response to natural or imposed changes can be made using Lane's relation (Simons, 1976) which is $Q.S$ $Q_s.d_{50}$. This relation states that the stream discharge (Q) times channel slope (S) is directly proportional to the sediment discharge (Q_s) times the mean bed material size (d_{50}). This relation will be kept in balance. That is, man-induced changes in a variable on one side of the relation will result in a natural change in the variables on the other side of the relation to maintain a proportionality. As an example, if water discharge (Q) is increased from mining and if the size of material is unchanged (d_{50}), then the sediment discharge will increase (Q_s). This can occur from increased bed and bank erosion.

There is a possibility of about five ground-water overburden relationships. These relationships are (1) overburden and coal seams are above the water table; (2) overburden and coal seams intercept the water table or overburden contains a confined aquifer above the coal; (3) overburden and coal occur above a confined aquifer; (4) overburden is within an unconfined aquifer, and coal seam is below; and (5) overburden that contains a confined aquifer is above the coal.

Within the study site, relationships (1), (2), and (4) exist. Where the overburden and coal seam occur above the water table or intersect it, very little difference can be expected between the composition of waters that pass through the overburden and the spoil overburden. This is probably true because the waters passing through undisturbed overburden come in contact with the same minerals before mining as after mining. The dissolved solids content of the spoil waters is always greater because of evaporation and increased surface area in the spoil material.

Where mining is carried out below the potentiometric surface, some dewatering will be necessary. The amount of withdrawal can only be determined after the mine plan is known. The permeability of the spoil differs drastically from undisturbed rocks. At first, permeability is greater than that of the undisturbed rocks, but as the spoil compacts, permeability is gradually reduced. This reduction in permeability will mean a decrease in the release of dissolved minerals.

The Lewis Shale contains secondary gypsum. Where the Fish Creek coal bed is extracted beneath the Lewis Shale, increases in sulfate concentrations can be expected in both Fish Creek and Foidel Creek.

RECOMMENDATIONS FOR ADDITIONAL HYDROLOGIC STUDY NEEDS

Existing streamflow gaging station records in northwestern Colorado reflect the hydrology of the higher mountains on the hydrology of the semiarid plateau. Much of the potential mining activity in northwestern Colorado is expected to occur in this transition area between the plateau and mountains, where minimal hydrologic information exists. The limited data that have been collected have been for a short time and it would be unreliable to transfer this hydrology to an ungaged watershed without correlation-type studies on longer term hydrologic data.

Due to these reasons, McCain and Jarrett (1976) indicate the methods presented to determine flood characteristics in this transition region should only be used as an interim procedure until additional data can be collected and analyzed to define the hydrology of the transition region with more reliability. Christensen (1978) of the Geological Survey, in cooperation with several Federal and State water agencies has initiated a hydrologic data collection and analysis study to help define the flood hydrology in the transition region of Colorado.

Continued streamflow data collection is imperative to (1) define existing runoff conditions, (2) evaluate the effects of proposed mining tracts, (3) develop reliable techniques to transfer hydrologic information from gaged to ungaged watersheds, and (4) record changes due to mining of an area. Additional data on ground-water chemistry are needed to (1) determine the mechanisms which presently control water quality, and (2) decide the nature of likely mining effects on these mechanisms.

CONCLUSION AND RECOMMENDATIONS FOR RECLAMATION

LEGAL REQUIREMENT OF MINE LAND RECLAMATION

Federal

The legal requirements for reclamation surface mined coal lands are covered principally by the following laws:

National Environmental Policy Act (Public Law 91-190)

Surface Mining Control and Reclamation Act (Public Law 95-87)

Federal Land Policy and Management Act (Public Law 94-529)

The following regulations enforce or control various aspects of surface mining, and affect various phases of land reclamation:

Title 43 CFR 3041 (BLM) Surface Management and Protection

Title 30 CFR 700 (OSM) Surface Mining Reclamation and Enforcement

Title 30 CFR 211 USGS Operating Regulations for Coal Mining

These regulations are being amended at various times. Anyone using these regulations should be sure they have the latest published material.

State

Reclamation of surface-mined coal lands are governed by the Colorado Open Mining Land Reclamation Act of 1973, as amended.

The rules and regulations for this Act are enforced by the Colorado Mined Land Reclamation Board. A permit bond and filing fee are required from mine operators and includes reclamation performance standards.

Local

Local regulations are not as explicit as State laws regarding surface mining and reclamation. Information on local regulations can be obtained from the outt County Court House, Steamboat Springs, Colorado.

RESOURCES AND LAND USE AFTER MINING

Return to Present Land Use

The entire surface area of the study site is privately owned. Approximately 75 percent of the area has been classified as being under cultivation. The remaining land is considered rangeland. One perennial stream, Fish Creek, and one intermittent stream, Foidel Creek, flow through the study site providing riparian habitat.

The cultivated land is used to produce small grain, wheat, and hay for winter livestock feed and improved pasture. The rangeland is used for grazing cattle. Deer and elk utilize the area for summer and winter range. Small mammals, songbirds, raptors, waterfowl, fur bearers, and upland game birds use the area seasonally.

Post-Mining Land Use Objectives

The post-mining objectives for the Fish Creek area are to return it to an approximate original landform and to its existing uses prior to mining.

Post-mining reclamation should ensure the continued present uses at approximately the same levels, or improve production if possible. Reclamation should ensure the return of air and water quality to or above the quality prior to mining. Reclamation techniques should also consider the visual and scenic values prior to mining and blend the land rehabilitation efforts into the surrounding landscape.

Cropland. Land that is going to be dryland farmed should be leveled and fertilized. If it cannot be farmed immediately after reclamation, it should be planted to a cover crop to reduce erosion.

Livestock Grazing. Livestock use occurs during the spring, summer, and fall. Some feeding is done around small farms in hay meadows during the winter months. To ensure reestablishment of vegetation, livestock should be excluded from the area for at least 2 years or until a suitable vegetative cover has been established.

Wildlife. Only 25 percent of the study area is in native range, and these areas should be returned to suitable big game habitat. The area bordering the cultivated land should be reestablished with species to provide protection and feed for deer and elk who use the area primarily during the winter and spring months. A buffer zone should be established along Foidel and Fish Creeks to provide riparian habitat for waterfowl, beaver, and the associated species.

Since small mammals, birds, amphibians, and reptile habitat would be destroyed with surface mining, the repopulation of the reclaimed site would be fairly rapid due to the short reproduction cycle of these mammals.

Watershed Management. Watershed management, as an existing land use, includes such soil and water objectives as the maintenance or improvement of water quantity, quality, and timing, and the maintenance or improvement of soil productivity and stability.

The reclamation objective for the study site includes returning the site's hydrologic condition back to the premining situation in terms of water quantity, quality, and timing of runoff. This applies both to surface and ground water.

The existing water quality meets State and Federal water quality standards. The mining plan should include provisions to maintain water quality after mining at or above the water quality standards. Returning the site hydrology back to the original condition will be a time-dependent process; however, this can be achieved within a period of a few years. The current uses of water within the study site, primarily water for crop production, livestock, and wildlife watering will be restored or improved after mining.

The reclamation objective also includes restoring soil productivity and stability to an equal or better condition than what existed before mining. On-site soil erosion will gradually decrease during the reclamation period as vegetation succession and development progresses and watershed cover improves.

RESOURCE PROBLEMS TO BE CONSIDERED DURING RECLAMATION

Quantity of Plant Growth Media Available

A land suitability survey was made of the site to determine the quality and availability of topsoil in the area. (The intensity of the survey and a description of the soils found were previously discussed in this report.) Utilizing this information, it is expected that 78.8 percent of the soils surveyed, class 1, 2, and 3, would be suitable for stockpiling for future use as a plant growth media. The remaining 21.2 percent of the study site, class 6 lands, have soil and/or topographic characteristics which do not meet the requirements of suitable material for stockpiling and reclaiming purposes.

Based on the land suitability specifications the class 1 lands, comprising about 43 percent of the area, would be most desirable as a source of revegation material for surfacing shaped spoils. These lands provide highly suitable material which is easily stripped and stockpiled for postmining use. The class 2 lands, which make up about 4 percent of the area, provide adequate stockpiling material, but the fine textured soil found in this class may require good placement practices and be more difficult to strip and stockpile. The class 3 lands comprise about 32 percent of the area but are marginal in their suitability because of poorer quality soil material.

Physical and Chemical Characteristics of Available Plant Growth Media

The class 1, 2, and 3 lands (and particularly the class 1 lands which should be identified and stockpiled for planting media) reflect very few adverse chemical conditions based on laboratory evaluations of the surface and upper soil materials (10 ft) taken relative to the land suitability surveys.

Physically, the class 2 lands and especially the class 3 lands have fine textured soils (clay, silty clay, and clay loam). Once disturbed, these soils lose the amount of natural structure they have, and water movement will be impeded. Wind erosion is likely, and additional land treatment will be necessary during reclamation revegetation.

The chemical and physical characterizations of the geologic overburden material (10 ft to bottom of coal seam) were characterized for five deep-hole locations on the site. Overall, these materials exhibited saline and soidic conditions. These or similar materials would be unfavorable for use as a plant growth media.

General Feasibility of Revegetation in Relation to Quantity and Quality of Planting Media

Important considerations for a successful revegetation program are climate, soil-water relationships, and soil, which affect stockpiling, shaping, and placement of material, seedbed preparation, planting, and plant growth. The soil quantity and quality evaluations indicate that a successful revegetation program is feasible if the topsoils or similar soils identified as suitable in the land suitability survey are used as a planting media.

Nutrient Deficiencies

A laboratory fertilizer analysis was not performed on the soils collected in the area. However, plant analysis in the greenhouse indicate that total P was below or near the critical level for corn and western wheatgrass grown on many of the soils. This was also true for total K.

Toxic Materials

Toxicity studies were not performed on the Fish Creek soil or overburden samples other than salinity and alkalinity contents. Neither of these are of the magnitude to be toxic in the materials selected as planting media. However, the soils designated as unsuitable in the study exhibited high levels of alkalinity and/or salinity and would be detrimental to plant growth. Plant analysis and growth studies in the greenhouse indicated a high relationship between increased sodium and/or salinity and decrease in yields.

Selected detailed analysis of trace elements and heavy metals that could be detrimental to surface and ground-water supplies and general consumption should be conducted prior to preparing a mining plan. If toxicities are encountered, regulations at the time will dictate handling and placement of these materials.

CLIMATOLOGICAL RECOMMENDATIONS FOR RECLAMATION

Variability of precipitation is the greatest constraint to revegetation.

- Reclamation strategy should include plans and resources for multiple seeding attempts since the establishment of vegetation is likely to fail occasionally. Supplemental water should be considered, although it probably would be more economically feasible to have an occasional failure and replanting.

- Mulching, special shaping, and contouring of the land surface should be considered for increasing soil water capacity and content and reducing evapotranspiration demand.

- Snow management techniques should be used to reduce the changes of winterkill of young plants, increase soil water into spring and summer, and decrease wind erosion and desiccation by occasional high winds.

Careful selection of plant species with respect to climate sensitivity is critical.

- Large daily variations in temperature and precipitation will demand that hardy species that can withstand rash changes during critical developmental stages be chosen.

- Fall seeding (for spring germination) is preferred to take full advantage of spring precipitation for plant establishment. Dates for fall seeding should be based on seed germination and ambient temperature requirements. Late fall warm periods may occur and cause premature germination resulting in a revegetation failure. Seeding in late October or early November looks to be the best time to avoid late warm periods.

- Critical climatic elements related to vegetation selection are shown in table 16. Where analyses have been completed, values of these critical climatic parameters have been filled in for the Fish Creek site. More detailed information concerning some of these analyses is given in the following text. Corresponding information of plant species for revegetation is generally not available. If plant specific requirements relating to climate constraints could be obtained, vegetation selection would be a straightforward task and table 16 could be used as a guide. In the absence of detailed plant information, alternative ways of using climatic information can be used.

  The first step is to consider the local native plant populations. While detailed quantitative information may not be available for these plants and conditions may not always be favorable for easy germination and establishment of these species, they clearly are adapted to the local climate and have proven their ability to survive. Local experience can be provided by reclamation specialists, seed suppliers, State extension agents, or others who have succeeded in establishing vegetation on nearby sites. Site-specific experimental field studies also can be carried out provide specific requirements for selected species.

Water

Foidel Creek is an intermittent stream and Fish Creek is a perennial stream within the study site. Most of the discharge of these two streams occurs in the spring in response to snowmelt. Average annual peak flows probably exceed 100 ft^3/s for both streams.

Plant requirements for vegetation selection

Climatic element	Units	Climatic profile for Fish Creek site*
Elevation above sea level	Feet	6850
Long-term mean annual air temperature	F°	42
April-September mean air temperature	F°	56
October-March mean air temperature	F°	29
High temperature extreme	F°	102
Hottest temperature experienced every year	F°	86
Low temperature extreme	F°	-45
Coldest temperature experienced every year	F°	- 7
Freeze free period	Days	131
Effective growing season (Probability = .5)	Days	182
Annual precipitation	Inches	16
Driest years (Probability = .10)	Inches	12.6
April-September total precipitation	Inches	8.1
Driest summers (Probability = .10)	Inches	5.2
October-April total precipitation	Inches	7.9
Driest winters (Probability = .10)	Inches	5.9
Annual potential evapotranspiration	Inches	23

*Estimates made for the Fish Creek Site based on Hayden and other Twentymile Park data.

The only ground-water system is the natural discharge to Fish and Foidel Creeks. Recharge to the ground-water system is probably less than 1 percent of the annual precipitation. Some recharge also occurs to the alluvium in both streams during high flow periods, but this water is released immediately to the streams as the stage decreases. Some direct recharge to deeper aquifers may occur where the streams cross faults. Ground-water movement within the study site is toward the northeast and movement of ground water out of the general area is towards the Yampa River. Discharges of approximately 10 gal/min are probably the maximum for small diameter wells in the area.

Average concentrations of major ions found in Foidel Creek meet Federal standards for both aquatic life and domestic drinking water supplies (US EPA, 1976). Suspended sediment concentrations in the two streams range from 16 to 75 mg/L. The larger concentration was obtained at a water discharge of 16 ft^3/s. Higher concentrations of sediment can be expected at higher flows.

The bed and banks of the Foidel Creek and Fish Creek channels consist primarily of silts and clays, and the valleys in which these streams flow consist primarily of fine-grain material. Disruptions near the channel could, therefore, increase suspended-sediment concentrations dramatically. Once in suspension, this fine-grain material could travel great distances downstream.

About five ground-water overburden relationships are possible. These relationships are (1) overburden and coal seams are above the water table; (2) overburden and coal seams intercept the water table or overburden contains a confined aquifer above the coal; (3) overburden and coal occur above a confined aquifer; (4) overburden is within an unconfined aquifer, and coal seam is below; and (5) overburden that contains a confined aquifer is above the coal.

Within the study area, conditions (1), (2), and (4) exist. Where the overburden and coal seam occur above the water table or intersect it, very little difference can be expected between the composition of waters that pass through the overburden and the spoil overburden. This is probably true because the waters passing through undisturbed overburden come in contact with the same minerals before mining as after mining. The dissolved-solids content of the spoil waters is always greater because of evaporation and increased surface area in the spoil material.

When mining is carried out below the potentiometric surface, some dewatering will be necessary. The amount of withdrawal can only be determined after the mine plan is known. The permeability of the spoil differs drastically from undisturbed rocks. At first, permeability is greater than that of the undisturbed rocks, but as the spoil compacts, permeability is gradually reduced. This reduction in permeability will mean a decrease in the release of dissolved minerals.

The Lewis Shale contains secondary gypsum. Where the Fish Creek coal bed is extracted beneath the Lewis Shale, increases in sulfate concentrations can be expected in both Fish Creek and Foidel Creek.

RECOMMENDATIONS FOR RECLAMATION

Handling and Placement of Soil and Bedrock

Mining techniques and regulations in force at the time mining occurs will dictate whether the suitable topsoil will be stockpiled for later use or moved directly from the mining site to areas being rehabilitated in the Fish Creek site.

Bedrock materials that are identified as unsuitable should be separated and placed at a depth greater than 10 ft below the reconstructed surface soil profile. Toxic materials should be identified and placed to prevent pollution of ground waters or contamination of surface water.

Hydrology and Erosion Control

Regulations will prevent any mining activites within the flood plain of Foidel or Fish Creeks. In addition, buffers should be installed between the mine and these main channels to prevent any sediment from reaching their waters. Tributary streams should be completely impounded above the mine site. It is likely that the first order tributaries to Foidel and Fish Creeks within the study site would be mined. The reclamation plan should include returning the channels to their original hydraulic characteristics. The channels should be restored to their original width/depth ratio or to a slightly greater width/depth ratio. Bed material sizes should be the same or larger than before mining. The channel gradient should be returned to the primary or lesser gradient.

The use of water control structures is acceptable and recommended. They should not be used where water retention and subsequent percolation will increase TDS concentrations. Large sediment basins should be located below spoils piles rather than in them. All water and erosion control structures should be designed to limit their effective life to not greater than 10 years and not less than 5 years. Following the reclamation period, remaining water or sediment control structures should be removed.

Reconstructed slopes should resemble premining conditions. Long slope segments over 4 to 5 percent should be interrupted by terraces. Slope segments between terraces should not exceed 50 to 100 feet in length depending on the slope steepness. When possible, south exposures should be minimized and graded relatively flat to lessen the microclimate effects on revegetation.

To improve infiltration, chiseling of the topsoil prior to planting is recommended. Also, on slopes over 20 percent, gouger pitting and/or contour furrowing is recommended. Again, any erosion control structures should have an effective life between 5 and 10 years.

Much of the area would be returned to cropland. Standard erosion control and soil conservation practices should be applied to reclaimed cropland. Waterways should be revegetated to a high density, permanent vegetation cover, and should be left untilled.

During the first year of reclamation, the cropland areas should be planted with a soil-building crop (legume). This crop should be incorporated back into the soil rather than harvested. Snow management practices (leave strips, tall brass barriers, or level bench terraces) could be employed and may eliminate the need for summer fallowing. Summer fallowing of the reclaimed areas should be discouraged for the first few years.

Selection of Species for Seeding

Regulations governing reclamation of surface mined lands require the land be returned to the same use as prior to mining.

Approximately 25 percent of the study site is in its native state, rangeland. The other 75 percent of the study site has been broken out of its native state and is being cultivated as either cropland, hayland, or pastureland.

Regulations require the native rangeland be returned to their natural state and revegetate with predominately native plants. This is an attempt to bypass the stages of secondary succession and produce a stable community.

However, the native vegetation as it occurred before mining will not be a stable community on postmined land. The entire ecosystem of mined land has been disrupted and changes have occurred from the microclimate to soils developing from different parent material.

The scheme of reclamation as it occurs today stockpiles soils of several different plant communities. This soil is used to cover an area that supported several plant communities before mining with a uniform depth of soil. A mixture of predominantly native species is then seeded, resulting in a single plant community being established where several occurred before mining. Through secondary succession, nature will establish a vegetative composition of specific plants adapted to the environmental conditions present following reclamation. How much of a change from revegetation efforts is not known.

Seeding a native mixture to initiate a later stage of secondary succession on strip-mined land is probably the most stable community we can establish with present day knowledge.

The following list of plant species represents the native potential vegetation for the study site. This list should be used in developing a species mixture for revegetation on the study site.

Grasses

Slender wheatgrass
Beardless wheatgrass
Western wheatgrass
Thickspike wheatgrass
Streambank wheatgrass
Bluebench wheatgrass
Green needlegrass
Letterman needlegrass
Columbia needlegrass
Needle-and-thread
Idaho fescue
Arizona fescue
Thurben fescue
Mountain brome
Nodding brome
Sandberg bluegrass
Big bluegrass
Nevada bluegrass
Prairie junegrass
Basin wildrye
Squirreltail
Mutton grass
Indian ricegrass

Forbs

Balsamroot
Eriogonum
Paintbrush
Geranium
Mules ear
Aster
Lupine
Western yarrow
Globemallow
Penstemon
Milk vetches
Groundsel
Bluebells
Phlox
Pussytoes
Golden weed
Onion
Native clovers
Herbaceous sage

Shrubs

Serviceberry
Bitterbrush
Snowberry
Winterfat
Four-wing saltbush
Fringed sagebrush
Big sagebrush
Low sagebrush
Silver sagebrush
Gamble oak
Chokecherry
Rose
Rabbitbrush

There are no identified endangered or threatened plant species on the study site.

Introduced species which have an adaptation to the area include

Tall wheatgrass
Pubescent wheatgrass
Intermediate wheatgrass
Smooth brome
Meadow brome
Russian wildrye
Fescue

Crested wheatgrass
Siberian wheatgrass
Orchard grass
Mammoth wildrye
Alfalfa
Aster
Vetch

Reclamation efforts should be toward the development of diverse and self-perpetuating plant communities. Precipitation patterns of the area indicate species which take advantage of early spring moisture, germinate early, and concentrate growth during the early growing season would be expected to establish and sustain most effectively. Other considerations which should influence the selection of species for revegetation includes (1) their natural adaptation for the area, (2) their ability to establish, (3) their ability to provide cover and soil stability, (4) their nutritional value and palatability for wildlife and domestic livestock, (5) their drought resistant, and (6) their susceptability to disease.

Selection of species to reestablish hayland and pastureland should take into account the six considerations previously mentioned with priority given to species which produce a high yield of good quality livestock feed. Species to consider for a hayland or pastureland seeding would include

- Alfalfa
- Smooth brome
- Meadow brome
- Intermediate wheatgrass
- Orchard grass
- Timothy grass
- Fescue

Cropland on the study site is primarily used to raise wheat. Other cereal grains adapted to the site include oats, barley, and rye.

Seeding Methods

Any practice that would enhance natural revegetation, on the area to be turned to rangeland, should be initiated in the reclamation process. Plant material cleared from the premining area should be saved and incorporated in the resurfacing soil or used as a mulch. Plant material removal and topsoil removal should follow production of a seed crop. This will allow a seed crop to be stockpiled with the soils and plant material.

Transplanting pads of natural shrubby vegetation will provide a quick wildlife cover and enhance natural revegetation. This can be accomplished with the use of a front-end loader. Mature healthy shrubs can also be transplanted with a tree spade. However, the front-end loader can transplant more area and provide a greater variety of vegetation.

If a mulch is applied for improvement of soil characteristics it should be incorporated into the soil before seeding. Adequate nitrogen must be available for the break down. If fertilizers are used to increase soil nutrient levels or to break down soil additives, they should be incorporated into the soil before or during seeding.

Following placement of the plant growth media (topsoil), a seedbed should be prepared. The area to be seeded should be ripped or subsoiled to alleviate compaction by heavy equipment and to enhance water infiltration. The soil preparation should provide an even and firm seedbed to allow regulation of uniform planting depth. Seed should be drilled on the contour or perpendicular to the slope. The depth placement of a seed is roughly proportional to its size. Most grass seed should be seeded to a depth of 1/2 to 3/4 of an inch. Small seed should be broadcast and seeded to a depth of 1/2 or 3/4 of an inch. This can be accomplished by allowing one-half of the small seed to be planted in the grass seed furrow and the other one-half broadcast behind the grass seed with the minimal amount of cover provided by the drill drags. Large seed such as brush, having long germination periods, should be seeded deeply enough to ensure a moisture supply during germination.

To enhance germination and obtain an established stand of grass, fall seeding is recommended. A rangeland or deep furrow drill should be used.

Bare-root stock or container grown shrubs should be planted in the early spring. The use of bare-root or container stock should be in conjunction with rodent and wildlife protection. To enhance establishment and growth of shrubs, select pockets, north aspects, or areas of snow accumulation where moisture accumulates during the wet seasons or where evapotranspiration ratio is low.

Seeding methods on the area returned to cropland should be those normally used in the area. The area to be seeded should be ripped or subsoiled to alleviate compaction by heavy equipment and to enhance water infiltration. The soil preparation should provide an even firm seedbed.

Post-Mining Land Management

Proper post management of the reclaimed area is essential if reclamation is to be successful. The reseeded rangeland and pastureland should be protected from grazing until vegetation is sufficiently developed and established to withstand grazing use without damaging the vegetation cover. Once established, a planned grazing system should be used to graze the area.

If weed growth prevents the survival of the seeded species during establishment, acceptable methods of weed control should be used.

A portion of the precipitation runoff should be intercepted by reservoirs following reclamation. These impoundments will provide water for wildlife and livestock use.

A rotation cropping system should be initiated on the cropland following reclamation. As a minimum, the cropping system should consist of a soil building crop after 3 or 4 years of soil depleting crops.

On all reclaimed land, regardless of its post-mining use, corrective measures should be taken to stop erosion. If noxious weeds invade the rehabilitation site, acceptable methods of removal should be used. Corrective measures should be taken to stop erosion. To maintain adequate fertility levels in the soil, a fertility program of several years may be necessary.

ALTERNATIVES FOR RECLAMATION

Increase Cultivated Lands or Improved Rangelands

It is assumed that the area will be reclaimed to the uses prior to mining. There is the possibility that more land could be put into crop production in areas where soils and slopes would permit it. Some areas may be feasible to restore with improved pastures for livestock. This use would produce more food for human consumption than is possible from native vegetation.

Wildlife Habitat

Since 75 percent of the areas are now being farmed, it is possible to develop more areas for wildlife habitat rather than returning it to its former use. Selecting native plant species adopted to the area that would be suitable for big game is important. Protection during establishment is also necessary to ensure complete rehabilitation.

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APPENDIX A
Geology

GEOLOGIC LOG OF HOLE NO DH1

SHEET 1 OF 1

PROJECT EMRIA-BLM FEATURE FISH CREEK SITE AREA STATE COLORADO

LOCATION SW1/4NW1/4S20T5NR86W GROUND ELEV 6800 ANGLE FROM HORIZ 80.0 DOWN

BEGUN 8-9-76 FINISHED 9-10-76 DEPTH TO BEDROCK 12.7 TOTAL DEPTH 30.0 BEARING

DEPTH TO WATER 5.0 9-1(-76 LOGGED BY J. TOMPKIN REVIEWED BY N.B. BENNETT

NOTES

PURPOSE OF HOLE TO DETERMINE EXTENT AND NATURE OF OVERBUROEN ABOVE FISH CREEK COAL

HOLE DRILLED WITH CME 75 TRUCK MOUNTEO ORILL RIG

HOLE TERMINATEO 10' BELOW COAL

COREO WITH SPLIT SPOON SAMPLER TO 12.0, WITH NO WIRE LINE TO 30.0

AIR USEO FOR DRILLING 12.0 TO 30.0

HOLE CASEO WITH HOLLOW STEM AUGER TO 10.5

WATER ENCOUNTERED IN COAL

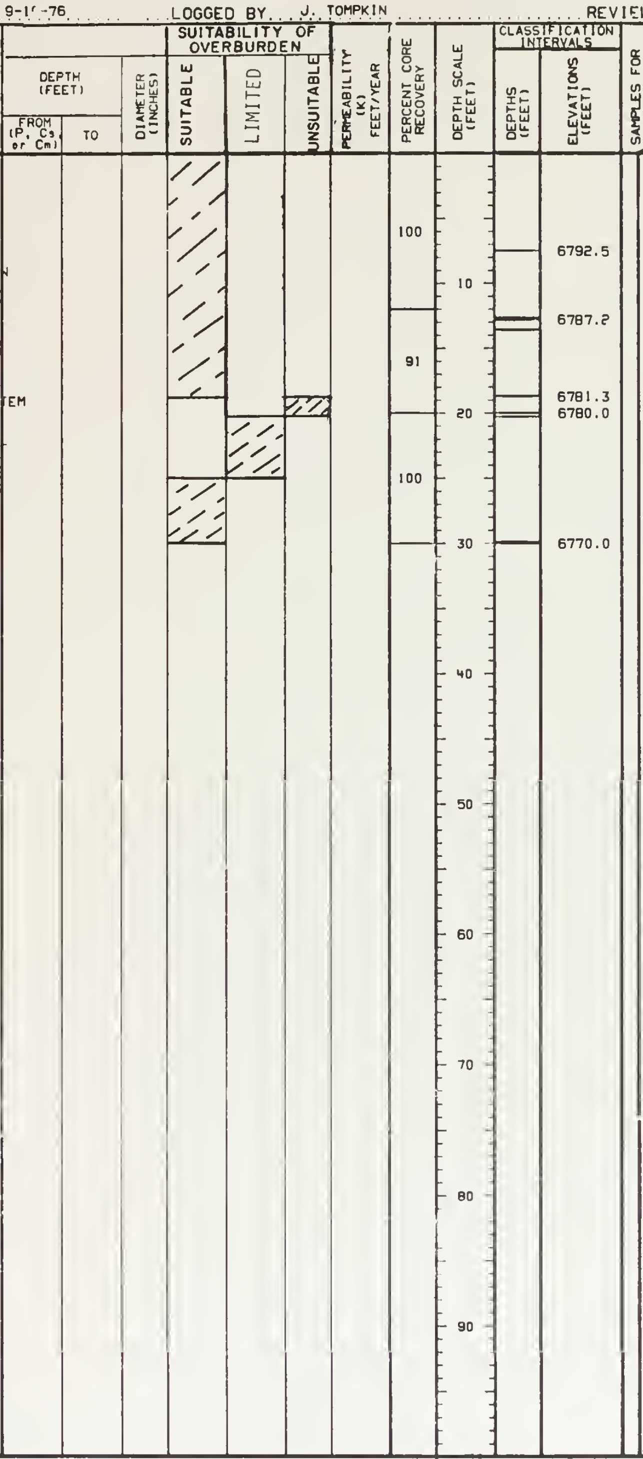
PERFORATEO PVC PIPE INSERTED IN HOLE TO 30.0'

•ELEVATION TAKEN FROM MILNER OUADRANOLE

P - FROM	R TO	TESTS BLOWS
1.5	2.0	11.0
2.0	2.5	12.0
2.5	3.0	25.0
3.0	3.5	15.0
3.5	4.0	20.
4.5	4.5	31.
4.5	5.0	20.0
5.0	5.5	38.
5.5	6.0	32.
6.0	6.5	20.
6.5	7.0	31.
7.0	7.5	31.
7.5	8.0	24.
8.0	8.5	34.0
8.5	9.0	52.
9.0	9.5	37.
9.5	10.0	67.0
10.0	10.5	85.0
10.0	11.0	40.
11.0	11.5	66.0
11.5	12.0	110.0

(P-R TESTS ARE FIELD APPROXIMATION: BLOW COUNTS TAKEN WHILE ADVANCING HOLE WITH SPLIT SPOON SAMPLER)

CORE LOGGEO WITHIN ONE HOUR OF REMOVAL FROM HOLE



CLASSIFICATION AND PHYSICAL CONDITION

0.0-12.8 RESIDUAL SOIL OEPOSIT

0.0-7.5 CLAY. YEL-BRN. SOIL DEVELOPMENT LIMIT ROOT ZONES IN UPPER 2 IN. POSSIBLE BENTONITE. SOME SILT,FEW PEBBLES .1 IN. ORIES IN COHESIVE COMPACTED AGGREGATES (MODE 1 IN.) WHICH OISAGGREGATE IN WATER. CACO3 COATINOS, FE STAINING INCREASING AT 3.0 TO 6.0 WITH RESULTING DECREASE IN COHESION. (CH)

7.5-12.8 CLAY-SHALE. YEL.-BRN.,GRAY STREAKS AND LENSES. WEATHEREO. BREAKS INTO CHIPS LESS THAN 1 IN. RED FE COATINGS ON RELICT BEODINO PLANES. ORIES INTO COHESIVE AGGREGATES ANO DISAGGREGATES IN WATER.

12.8-30.0 HOLDERNESS MEMBER, WILLIAMS FORK FORMATION, MESA VEROE GROUP

12.8-13.6 MUOSTONE. CALCAREOUS. OK GRAY. HOMOGENEOUS,COHESIVE. JOINT OIPPING 85 DEGREES. HARDNESS 5. CORE MODE .3'

13.6-18.7 SILTSTONE. CONTAINS LESS THAN 1 PER CENT SAND. CALCAREOUS,SCATTEREO CARBONACEOUS FRAGMENTS. DK GRAY. HARDNESS5. CORE MOOE .5'

18.7-20.0 COAL. PYRITE SPECK. SAMPLE TAKEN.

20.0-20.3 COALY SHALE

20.3-30.0 LIMESTONE. OIRTY,GRAOING TO MUDSTONE AT 20.3-24.1,25.8-26.8,28.7-30.MEO.GRAY. HOMOGENEOUS TEXTURE,COHESIVE. COAL FRAG.,PYRITE AT 21.0,FOSSIL AT 21.5. FRACTURE BROKEN TO CONCHOIDAL. HARONESS 6. CORE MOOE .6'.

NOTE: AFTER 3 MONTHS ORYINO ANO FREEZE-THAW WEATHERINO MUOSTONE LOSES COHESION AND SLAKES TO FRAGS .01-.3 IN. EXCEPT WHERE MUDSTONE ORADES TO LIMESTONE.

COMMENTS:

GEOLOGIC LOG OF HOLE NO DH2

SHEET 1 OF 3

PROJECT EMRIA-BLM FEATURE FISH CREEK SITE AREA STATE COLORADO
LOCATION SECORNERSW1/4S21T5NR86W GROUND ELEV. 6810 ANGLE FROM HORIZ 90.0 DOWN
BEGUN 9-19-76 FINISHED 9-21-76 DEPTH TO BEDROCK 14.0 TOTAL DEPTH 283.3 BEARING
DEPTH TO WATER 5.6 9-19-76 LOGGED BY J. TOMPKIN REVIEWED BY N.B.BENNETT

NOTES	DEPTH (FEET) FROM (P, Cs, or Cm)	DEPTH (FEET) TO	DIAMETER (INCHES)	SUITABILITY OF OVERBURDEN: SUITABLE	LIMITED	UNSUITABLE	PERMEABILITY (K) FEET/YEAR	PERCENT CORE RECOVERY	DEPTH SCALE (FEET)	CLASSIFICATION INTERVALS: DEPTHS (FEET)	ELEVATIONS (FEET)	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION

PURPOSE TO DETERMINE EXTENT AND NATURE OF OVERBURDEN ABOVE FISH CREEK COAL

HOLE DRILLED WITH CME75 TRUCK MOUNTED DRILL RIG

HOLE TERMINATED 25' BELOW COAL

CORED WITH SPLIT SPOON SAMPLER TO 10.0 CORED WITH NQ WIRELINE TO 115.

DRILLED WITH AIR 10.-14.0 WITH LOSS OF CORE DRILLED WITH WATER 14.0-115.0

4' OF CORE STUCK IN INNER BARREL AT 16.0 NO RETRIEVAL

HOLE CASED WITH HO[illegible] STEM AUGER TO 10.0

PERFORATED PVC PIPE INSERTED IN HOLE AFTER GEOLOGIC SURVEY TOOK HOLE OVER FOR DRILLING TO 283.

*ELEVATION FROM RATTLESNAKE BUTTE QUADRANGLE

P - R TESTS

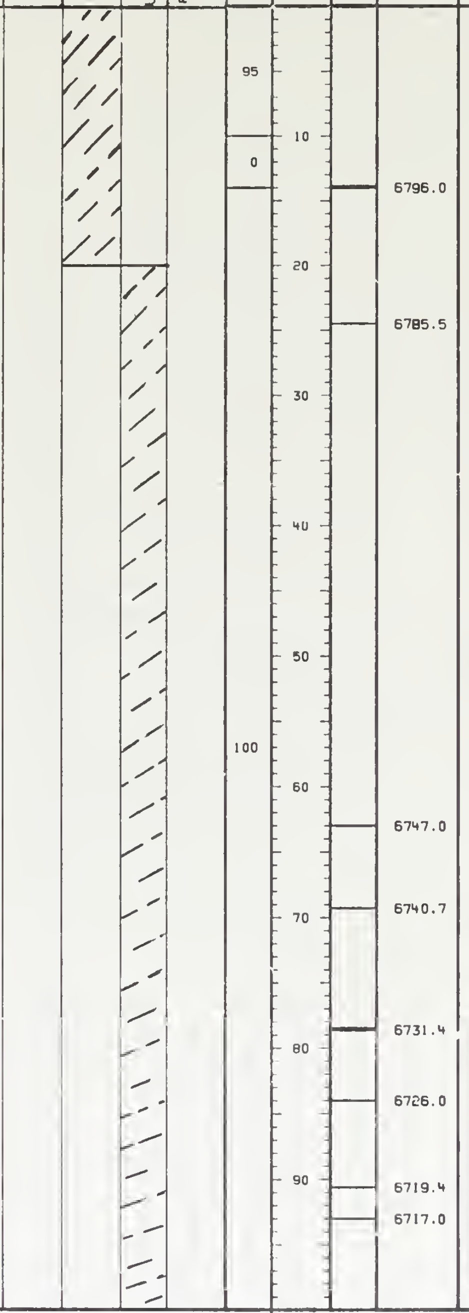
FROM	TO	BLOWS
0.0	0.5	5.
0.5	1.0	7.
1.0	1.5	12.
1.5	2.0	12.
2.0	2.5	11.
2.5	3.0	15.
3.0	3.5	15.
3.5	4.0	17.
4.0	4.5	25.
4.5	5.0	18.
5.0	5.5	28.
5.5	6.0	31.
6.0	6.5	20.
6.5	7.0	36.
7.0	7.5	42.
7.5	8.0	43.
8.0	8.5	67.
8.5	9.0	47.
9.0	9.5	42.
9.5	10.0	71.

(P-R TESTS ARE FIELD APPROXIMATION: BLOW COUNTS TAKEN WHILE ADVANCING HOLE WITH SPLIT SPOON SAMPLER)

CORE LOGGED WITHIN ONE HOUR AFTER REMOVAL FROM HOLE

CORE TO 115' RETURNED TO USBR. HOLE CONTINUED BY USGS, CORE FROM 115-283.3 RETAINED BY USGS, BUT LOGGED ON SITE

NOTE: AFTER 3 MONTHS DRYING AND FREEZE-THAW WEATHERING, MUDSTONE LOSES COHESION AND CRUMBLES TO FRAGS. .01-.3 IN., EXCEPT WHERE MUDSTONE GRADES TO LIMESTONE



0.0-14.0 RESIDUAL SOIL DEPOSIT

0.0-14.0 CLAY, YEL.BRN. COMPACTED. FORMS COHESIVE AGGREGATES WHICH DISINTEGRATE IN WATER. POSSIBLE BENTONITE. CACO3 CRYSTALS AND COATINGS,2.0-5.0. SMALL AMOUNT RED AND YELLOW FE STAINING. (CH)

14.0-78.6 LEWIS FORMATION

14.0-24.5 MUDSTONE. DARK GRAY, CLAYEY. JOINT DIPPING 25 DEGREES. APPARENT BRECCIATION AT 23.0-24.0. PARTINGS SMOOTH TO SLIGHTLY ROUGH. HARDNESS 4.

24.5-63.0 MUDSTONE. DARK GRAY, CALCAREOUS WITH CARBONACEOUS FRAGMENTS AND FOSSILS IN SCATTERED PLACES. COHESIVE. HOMOGENEOUS TEXTURE. HARDNESS 5. CORE MODE 2'-6'. LIMESTONE NODULE AT 59.0

63.0-69.3 MUDSTONE. DARK GRAY. BRECCIATED. CLAYEY. EXTREME FISSILITY APPARENT WHEN BROKEN. SLICKENSIDED JOINTS DIPPING 40 DEGREES.

69.3-78.6 LIMESTONE. DARK GRAY. CARBONACEOUS FRAGMENTS. SOME FOSSILS. HARDNESS 5-6. CORE MODE 2'. CALCAREOUS CLAY AT 72.8. TURBULENT INTERBEDDING WITH CARBONACEOUS SILT 76.3-78.6. COAL BAND AT 76.7

78.6-267.7 HOLDERNESS MEMBER, WILLIAMS FORK FORMATION, MESA VERDE GROUP

78.6-84.0 MUDSTONE. DARK GRAY. CALCAREOUS, CARBONACEOUS. FOSSILIFEROUS. LIMESTONE AT 82.0. HARDNESS 5. CORE MODE 2.5'.

84.0-90.6 COAL INTERVAL.SAMPLE TAKEN 84.0-89.9. COALY SHALE AT 88.2-89.9. COAL AT 89.6-89.9, INTERBEDDED SS AND COAL, 89.9-90.6.

90.6-93.0 SANDSTONE. BUFF. CONTAINS WHITE CHERT, QUARTZ GRAINS. FINE-GRAINED, PERMEABLE, WELL-CEMENTEDWITH WHITE CLAY. HARDNESS 6. CORE MODE 2.4'.

93.0-118.5 SANDSTONE. WHITE TO LIGHT GRAY, MED.-FINE GRAINED. SALT AND PEPPER COLORED GRAINS, ROUNDED TO SUB-ROUNDED, PERMEABLE. CLAY CEMENT VARIABLE, ALMOST UNCONSOL. IN PLACES. HARDNESS 5. CORE MODE 4-6'. CRUMBLES EASILY WITH FINGERS.

118.5-138.0 SANDSTONE, MED. GRAINED, PERMEABLE. SL. CALCAREOUS,FRIABLE,LT. GRAY. HARDNESS 4-5. AT 130, INTERBEDDED BLACK CARB. MDSTONE. AT 137, BLACK LAMINAE INDICATE CROSS-BEDDINO.

138.0-144.0 SANDSTONE. FINE-GRAINED, DENSE, CALCAREOUS. HARDNESS 5.

144.0-146.3 LIMESTONE, DIRTY, LT. GRAY.

146.3-158.7 LIMESTONE, SANDY, WITH TURBULENT BLACK INFILLINGS AND CARBONACEOUS COATINGS. SLICKENSIDED JOINTS AND BRECCIATED ZONES.

158.7-161.5 MUDSTONE. CLAYEY. SICKENSIDED JOINTS DIP 50 DEGREES.

161.5-168.5 LIMESTONE, SANDY,COHESIVE. GRAY.

168.5-208.8 SILTSTONE,BLACK, TURB. INTERBEDDED W. LIMESTONE, SANDY, ORAY. BEDS DIP APPROX. 13 DEGREES.

208.8-223.2 MUDSTONE. DENSE, SOME CARBONACEOUS FRAGS. CALCAREDUS, FEW FOSSILS. DK. GRAY.

223.2-247.1 MUDSTONE, INTERBEDDED WITH LIMESTONE, LS. 1 IN. LAYERS TO 245, UP TO 4 IN. LAYERS,245-247.

247.1-253.0 MUDSTONE WITH BRECCIATED ZONES, CLAY LENSES. DK. GRAY.

253.0-267.7 SANDSTONE, GRAY, INTERBEDDED WITH BLACK MUDSTONE.

267.7-283.3 TWENTYMILE SANDSTONE MEMBER, WILLIAMS FORK FORMATION, MESA VERDE GROUP

267.7-283.3 SANDSTONE, FINEORAINED, SALT AND PEPPER COLORED ORAINS.

COMMENTS:

GEOLOGIC LOG OF HOLE NO DH2

SHEET 2 OF 3

PROJECT EMRIA-BLM FEATURE FISH CREEK SITE AREA STATE COLORADO

LOCATION SECORNERSH1/4S21T5NR86W GROUND ELEV 6910 ANGLE FROM HORIZ 90.0 DOWN

BEGUN 9-19-76 FINISHED 9-21-76 DEPTH TO BEDROCK 14.0 TOTAL DEPTH 293.3 BEARING

DEPTH TO WATER 5.6 9-19-76 LOGGED BY J. TOMPKIN REVIEWED BY N.B.BENNETT

NOTES	DEPTH (FEET) FROM (P, Cs, or Cm)	DEPTH (FEET) TO	DIAMETER (INCHES)	SUITABILITY OF OVERBURDEN SUITABLE	LIMITED	UNSUITABLE	PERMEABILITY (K) FEET/YEAR	PERCENT CORE RECOVERY	DEPTH SCALE (FEET)	CLASSIFICATION INTERVALS DEPTHS (FEET)	ELEVATIONS (FEET)	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
						▨			110				
											6691.5		
									120				
									130				
											6672.0		
									140				
											6666.0		
											6663.7		
								100	150				
											6651.3		
									160				
											6649.5		
											6641.5		
									170				
									180				
									190				

COMMENTS:

GEOLOGIC LOG OF HOLE NO DH2

SHEET 3 OF 3

PROJECT EMRIA-BLM FEATURE FISH CREEK SITE AREA STATE COLORADO
LOCATION SECORNERSW1/4S21T5NR86W GROUND ELEV 6810 ANGLE FROM HORIZ 90.0 DOWN
BEGUN 9-19-76 FINISHED 9-21-76 DEPTH TO BEDROCK 14.0 TOTAL DEPTH 283.3 BEARING
DEPTH TO WATER 5.6 9-19-76 LOGGED BY J. TOMPKIN REVIEWED BY N.B.BENNETT

NOTES	DEPTH (FEET) FROM (P, Cs or Cm)	DEPTH (FEET) TO	DIAMETER (INCHES)	SUITABILITY OF OVERBURDEN: SUITABLE	SUITABILITY OF OVERBURDEN: LIMITED	SUITABILITY OF OVERBURDEN: UNSUITABLE	PERMEABILITY (K) FEET/YEAR	PERCENT CORE RECOVERY	DEPTH SCALE (FEET)	CLASSIFICATION INTERVALS: DEPTHS (FEET)	CLASSIFICATION INTERVALS: ELEVATIONS (FEET)	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
											6601.2		
									210				
									220				
											6586.8		
									230				
									240				
								100					
											6562.9		
									250				
											6557.0		
									260				
											6542.3		
									270				
									280				
											6526.7		
									290				

COMMENTS:

FEATURE FISH CREEK SITE AREA SHEET 3 OF 3 HOLE NO DH2

GEOLOGIC LOG OF HOLE NO DH3

SHEET 1 OF 2

PROJECT EMRIA-BLM FEATURE FISH CREEK SITE AREA STATE COLORADO
LOCATION NE CORNER NW1/4S27T5NR86W GROUND ELEV 6810 ANGLE FROM HORIZ 80.0 DOWN
BEGUN 9-16-76 FINISHED 9-17-76 DEPTH TO BEDROCK 37.0 TOTAL DEPTH 160.8 BEARING
DEPTH TO WATER 10.3 9-17-76 LOGGED BY J. TOMPKIN REVIEWED BY N. B. BENNETT

NOTES | DEPTH (FEET) FROM (P, Cs or Cm) | TO | DIAMETER (INCHES) | SUITABILITY OF OVERBURDEN: SUITABLE | LIMITED | UNSUITABLE | PERMEABILITY (K) FEET/YEAR | PERCENT CORE RECOVERY | DEPTH SCALE (FEET) | CLASSIFICATION INTERVALS: DEPTHS (FEET) | ELEVATIONS (FEET) | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION

NOTES

PURPOSE TO DETERMINE EXTENT AND NATURE OF OVERBURDEN ABOVE FISH CREEK COAL

HOLE DRILLED WITH CME 75 TRUCK MOUNTED DRILL RIG

HOLE TERMINATED AT 160' AT SANDSTONE KNOWN TO UNDERLIE COAL. NO COAL ENCOUNTERED

CORED WITH SPLIT SPOON SAMPLER TO 37.0 WITH NQ WIRELINE TO 160.

DRILLED WITH AIR TO 44.5 WITH WATER TO 160'

HOLE CASED WITH HOLLOW STEM AUGER TO 39.0

HIT WATER AT 11.0

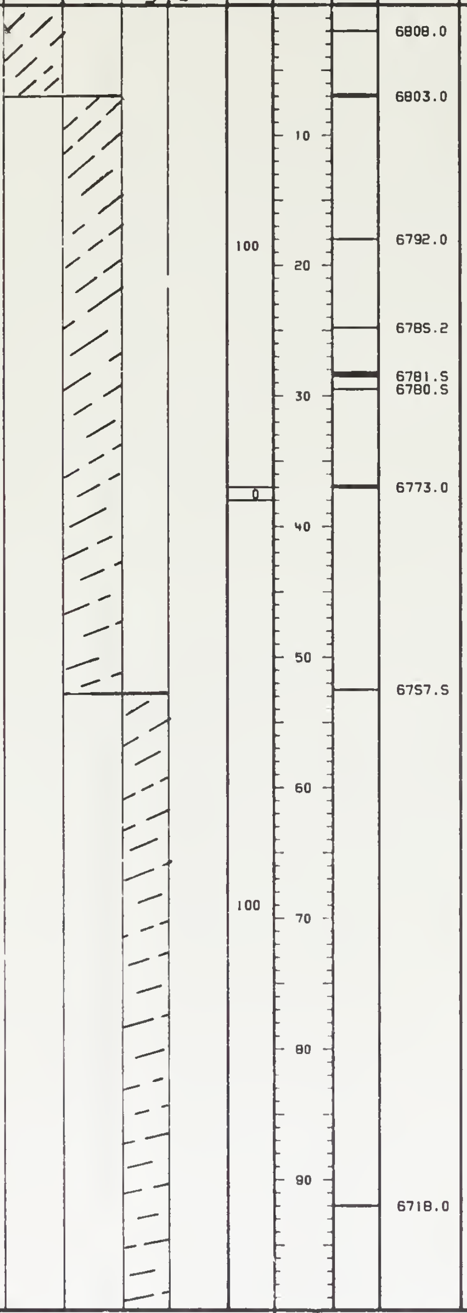
WATER LOSS CONTINUAL BELOW 44.5

PERFORATED PVC PIPE INSERTED TO 40.0 AFTER COLLAPSE OF HOLE

*ELEVATION FROM RATTLESNAKE BUTTE QUADRANGLE

P - R TESTS

FROM	TO	BLOWS
0.0	0.5	2.
0.5	1.0	4.
1.0	1.5	7.
1.5	2.0	11.
2.0	2.5	12.
2.5	3.0	12.
3.0	3.5	2.
3.5	4.0	13.
4.0	4.5	13.
4.5	5.0	8.
5.0	5.5	7.
5.5	6.0	7.
6.0	6.5	1.
6.5	7.0	2.
7.0	7.5	4.
7.5	8.0	7.
8.0	8.5	11.
8.5	9.0	11.
9.0	9.5	8.
9.5	10.0	8.
10.0	10.5	11.
10.5	11.0	6.
11.0	11.5	8.
11.5	12.0	13.
12.0	12.5	8.
12.5	13.0	10.
13.0	13.5	13.
13.5	14.0	15.
14.0	14.5	16.
14.5	15.0	21.
15.0	15.5	8.
15.5	16.0	9.
16.0	16.5	12.
16.5	17.0	18.
17.0	17.5	19.
17.5	18.0	14.
18.0	18.5	4.
18.5	19.0	6.
19.0	19.5	7.
19.5	20.0	3.
20.0	20.5	5.
20.5	21.0	5.
21.0	21.5	3.
21.5	22.0	3.
22.0	22.5	4.
22.5	23.0	5
23.0	23.5	5.
23.5	24.0	9.
24.0	24.5	9.
24.5	25.0	17.
25.0	25.5	44.
25.5	26.0	1.
26.0	26.5	1.
26.5	27.0	2.
27.0	27.5	5.
27.5	28.0	8.
28.0	28.5	12.
28.5	29.0	7.
29.0	29.5	12.
28.5	30.0	17.



CLASSIFICATION AND PHYSICAL CONDITION

0.0-7.0 SOIL ZONE

0.0-2.0 SILT, SANDY. BROWN, ORGANIC, FRIABLE (ML)

2.0-7.0 SILT, SANDY, BUFF, FRIABLE. (ML)

7.0-28.5 ALLUVIUM

7.0-18.0 SAND. BLACK AND WHITE GRAINS. QUARTZ, CHERT, BLACK MINERAL, FINE-GRAINED, ROUNDED-SUBROUNDED. UNCONSOLIDATED. SOME FE STAINING. (SC)

18.0-24.8 CLAY. UPPER .5' YELLOW, FE STAINED, REMAINDER GRAY. SOME CARBONACEOUS FRAGMENTS, MICA. SLIGHTLY CALCAREOUS. CONTAINS SOME GRAY SAND BELOW 24.0
(CH)

24.8-28.2 SAND. ORANGE-BUFF,FINE-GRAINED, UNCONSOLIDATED. HIGHLY FE STAINED. SOME APPARENT HORIZONTAL BEDDING PLANES. (SC)

28.2-28.5 GRAVEL. RED-ORANGE. SANDSTONE, QUARTZ PEBBLES, SUBROUNDED-ROUNDED. MAXIMUM SIZE .5 IN.. (GW-GC)

28.5-37.0 POSSIBLE WEATHERED BEDROCK

28.5-29.5 CLAY. GRAY, SANDY. (CL-CH)

29.5-37.0 SAND. BUFF TO ORANGE WHERE FE STAINED. FINE-GRAINED. WHITE CLAY MEMBRANES, SOME BLACK HORIZONS. GRAY CLAY BALLS 33.0-36.0

37.0-160.8 HOLDERNESS MEMBER, WILLIAMS FORK FORMATION, MESA VERDE GROUP

37.0-52.5 SANDSTONE. GRAY. CALCAREOUS. GRAINS PRIMARILY QUARTZ. MICA FLAKES. FINE-GRAINED. BLOCKY PARTINGS. CARBONACEOUS FRAGMENTS (1 PERCENT) CARBONACEOUS BANDS .2-1 IN. APART FROM 42.5-46.0. HARDNESS 6. CORE MODE .5'.

52.5-92.0 SANDSTONE AND MUDSTONE. APPROX. 10' SEQUENCES INCLUDE:
SANDSTONE, FINE-GRAINED, GRAY .6-2.2' BEDS (10 PERCENT)
SANDSTONE(GRAY) INTERBEDDED WITH MUDSTONE (DARK GRAY-BLACK) IN LAMINAE AND INFILLINGS SHOWING TURBULENT AND SLUMP BEDDING WITH SANDSTONE COMPRISING 5-50 PERCENT(80 PERCENT)
MUDSTONE, BRECCIATED, CLAYEY. HIGHLY CALCAREOUS. CARBONACEOUS, COAL FRAGMENTS. (10 PERCENT)
SANDSTONE HARDNESS 6, CORE MODE 1.5.
CLAYEY MUDSTONE HARDNESS 3-4, DISINTEGRATES EASILY. COAL AT 57.0, 69.0, 71.0.

82.0-140.0 MUDSTONE. BLACK. MINOR GRAY SANDSTONE INCLUSIONS. CARBONACEOUS STEMS AND FRAGMENTS. CLAY AT 92.,103.5,104.5, 123-129, 135-139. HARDNESS 5, CORE MODE .5-3.0

140.0-151.5 SANDSTONE. GRAY. FINE-GRAINED. CALCAREOUS, CARBONACEOUS. FOSSILS. COHESIVE. HARDNESS 6. CORE MODE 5.0'
AT 146.6-148.3 GRAIN SIZE BECOMES MED.-FINE, CEMENT IS GREENISH. BELOW 148.0, DARK GRAY MUDSTONE LAMINAE, TURBULENT BEDDING.

151.5-154.0 MUDSTONE. CLAYEY, BRECCIATED. MANY CLAY LAYERS.

154.0-160.8 SANDSTONE. GRAY. MED.-FINE GRAINED. HARDNESS 5. WHEN FRACTURED BECOMES ALMOST UNCONSOLIDATED.

NOTE:
CORE LOGGED WITHIN 1 HOUR AFTER REMOVAL FROM HOLE. AFTER 3 MONTH DRYING AND FREEZE-THAW WEATHERING MUDSTONE LOSES COHESION AND SLAKES TO FRAGS. .01-.3 IN. EXCEPT WHERE MUDSTONE GRADES TO LIMESTONE.

COMMENTS:

GEOLOGIC LOG OF HOLE NO DH3

SHEET 2 OF 2

PROJECT EMRIA-BLM FEATURE FISH CREEK SITE AREA STATE COLORADO

LOCATION NE CORNER NW1/4S27T5NR86W GROUND ELEV 6810 ANGLE FROM HORIZ 90.0 DOWN

BEGUN 9-16-76 FINISHED 9-17-76 DEPTH TO BEDROCK 37.0 TOTAL DEPTH 160.8 BEARING

DEPTH TO WATER 10.3 9-17-76 LOGGED BY J. TOMPKIN REVIEWED BY N. B. BENNETT

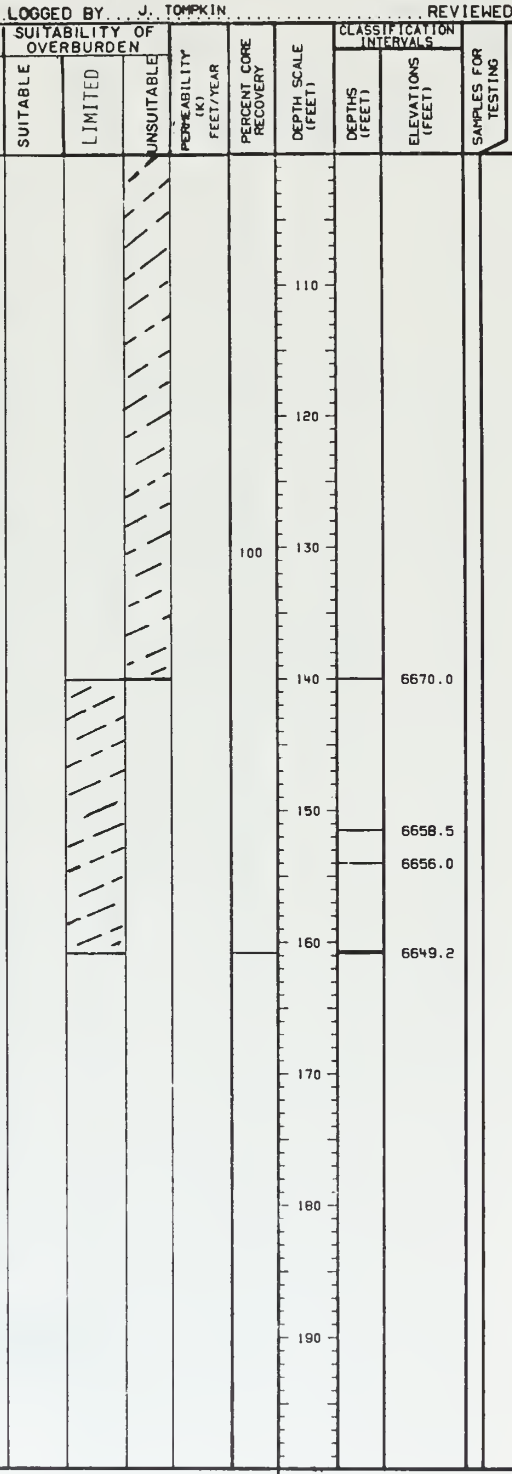
NOTES

30.0	30.5	21.
30.5	31.0	19.
31.0	31.5	19.
31.5	32.0	7.
32.0	32.5	14.
32.5	33.0	17.
33.0	33.5	4.
33.5	34.0	9.
34.0	34.5	6.
34.5	35.0	2.
35.0	35.5	2.
35.5	36.0	4.
36.0	36.5	5
36.5	37.0	20.

(P-R TESTS ARE FIELD APPROXIMATION BLOW COUNTS TAKEN WHILE ADVANCING HOLE WITH SPLIT SPOON SAMPLER)

DEPTH (FEET): FROM (P, Cs, or Cm) / TO

DIAMETER (INCHES)



CLASSIFICATION AND PHYSICAL CONDITION

COMMENTS:

FEATURE FISH CREEK SITE AREA SHEET 2 OF 2 HOLE NO DH3

GEOLOGIC LOG OF HOLE NO DH4

SHEET 1 OF 3

PROJECT EMRIA-BLM FEATURE FISH CREEK SITE AREA STATE COLORADO
LOCATION NE CORNER S21T5NR86W GROUND ELEV. 6680. ANGLE FROM HORIZ 80.0 DOWN
BEGUN 8-1-76 FINISHED 8-6-76 DEPTH TO BEDROCK 17.5 TOTAL DEPTH 207.5 BEARING
DEPTH TO WATER 10.7 9-6-76 LOGGED BY J. TOMPKIN REVIEWED BY N. B. BENNETT

NOTES

PURPOSE TO DETERMINE EXTENT AND NATURE OF OVERBURDEN ABOVE FISH CREEK COAL

DRILLED WITH CME 75 TRUCK MOUNTED DRILL RIG

HOLE TERMINATED 10' BELOW COAL

CORED WITH SPLIT SPOON SAMPLER TO 21.5 WITH NQ WIRELINE TO 207.5

HIT WATER AT 15.5

HOLE CASED WITH HOLLOW STEM AUGER TO 54.5

HOLE DRILLED WITH AIR TO 58.3. DRILL STUCK AT 56.3 HOLE SATURATED WITH DIESEL FUEL TO RELE. .. HOLE DRILLED WITH WATER 58.3 TO 207.5

CORE HAMMERED FROM INNER BARREL WITH SOME RESULTING FRAGMENTATION

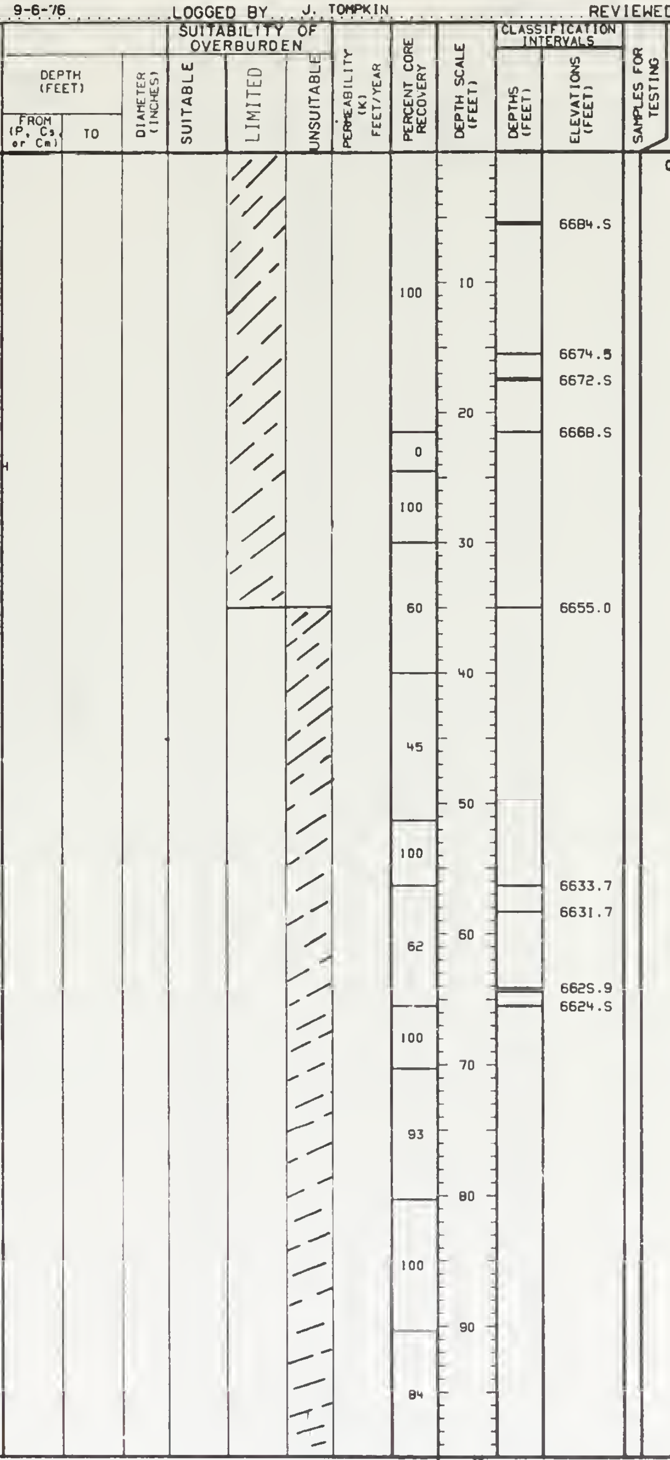
PERFORATED PVC PIPE INSERTED IN HOLE TO 140'

*ELEVATION FROM MILNER QUADRANGLE

P - R TESTS

FROM	TO	BLOWS
0.0	0.5	2.
0.5	1.0	4.
1.0	1.5	7.
1.5	2.0	9.
2.0	2.5	12.
2.5	3.0	11.
3.0	3.5	14.
3.5	4.0	19.
4.0	4.5	20.
4.5	5.0	8.
5.0	5.5	16.
5.5	6.0	20.
6.0	6.5	11.
6.5	7.0	13.
7.0	7.5	20.
8.0	8.5	8.
8.5	9.0	12.
9.0	9.5	14.
9.5	10.0	18.
10.0	10.5	8.
10.5	11.0	11.
11.0	11.5	9.
11.5	12.0	12.
12.5	13.0	12.
13.0	13.5	7.
13.5	14.0	11.
14.0	14.5	7.
14.5	15.0	15.
15.0	15.5	16.
15.5	16.0	14.
16.0	16.5	15.
16.5	17.0	21.
17.0	17.5	11.
17.5	18.0	15.
18.0	18.5	15.
18.5	19.0	28.
19.0	19.5	83.
19.5	20.0	26.
20.0	20.5	49.
20.5	21.0	45.
21.0	21.5	80.

P-R TESTS ARE FIELD APPROXIMATION: BLOW COUNTS TAKEN WHILE ADVANCING HOLE WITH SPLIT SPOON SAMPLER



CLASSIFICATION AND PHYSICAL CONDITION

0.0-5.5 SOIL ZONE

0.0-5.5 CLAY, DARK GRAY-BROWN. BENTONITE. DRIES INTO COHESIVE AGGREGATES (MODE 1.5 IN.) WHICH DISAGGREGATE IN WATER. (CH)

5.5-17.5 ALLUVIUM

5.5-15.5 CLAY. YELLOW. 2 IN. CACO3 COATINGS AT 6.0 AND 7.5 CACO3 STRINGERS TO 11.0 RED AND YELLOW FE STAINED SHALY CHIPS. OCCASIONAL PEBBLES. DRIES TO COHESIVE 3 IN. AGGREGATES WHICH DISAGGREGATE IN WATER.

15.5-17.5 GRAVEL. SUBROUNDED FRAGMENTS UP TO 1 IN. SCHIST, SANDSTONE, QUARTZ, BASALT. (GC)

17.5-194.8 LEWIS FORMATION

17.5-21.5 SHALE. WEATHERED ZONE. GRADES FROM YELLOW TO GRAY WITH DEPTH. RELICT CONCRETIONS,ANGULAR PARTINGS NO BEDDING PLANES. GRADES FROM NON-INDURATED TO HARDNESS 3 WITH DEPTH.

21.5-35.0 MUDSTONE.* SLIGHTLY CALCAREOUS. MICA FLAKES. DARK GRAY-BLACK. HARDNESS 4-5. SOME SEPARATION UPON DRYING ALONG SMOOTH HORIZONTAL PLANES. SEPARATES ALONG SMOOTH PLANES WITH HAMMER BLOW INTO .3-3 IN. SEGMENTS. CORE MODE 3 IN.. SOME FISSILITY UPON DRYING. WET CUTTINGS HIGHLY PLASTIC.

35.0-56.3 MUDSTONE.* MICA FLAKES, MINOR CACO3. CARBONACEOUS FRAGMENTS TO 50. DARK GRAY TO BLACK. TEXTURE HOMOGENEOUS NO APPARENT BEDDING. COHESIVE. HARDNESS 5. PARTING SURFACES HACKLY. CORE MODE 4 IN.. CAN BE BROKEN WITH HANDS INTO 2-3 IN. SEGMENTS.

56.3-58.3 MUDSTONE.* SATURATED WITH DIESEL FUEL (SEE DRILLING CONDITIONS)

58.3-64.1 MUDSTONE.* DARK GRAY TO BLACK. FINELY DIVIDED SCATTERED CARBONACEOUS FRAGMENTS. HOMOGENEOUS, COHESIVE. HARDNESS 6.

64.1-64.4 LIMESTONE. MED. GRAY. CARBONACEOUS. HARDNESS 7. FOSSIL BRACHIOPOD, 64.4

64.4-65.5 MUDSTONE. DARK GRAY, FRACTURED AND BRECCIATED. CLAYEY.

65.5-194.5 MUDSTONE.* DARK GRAY-BLACK. MICA FLAKES. CALCAREOUS. CARBONACEOUS FRAGMENTS. TEXTURE HOMOGENEOUS EXCEPT WHERE FOSSILS OR CARBONACEOUS CONCENTRATIONS OCCUR. NO APPARENT BEDDING. COHESIVE CORE CAN BE BROKEN WITH HANDS INTO 4-6 IN. SEGMENTS WITH PARTINGS SMOOTH TO HACKLY. CORE MODE 1-2.5'.MODERATELY FOSSILIFEROUS 110-190 BRACHIOPODS, CLAMS, AMMONITES, WHITE FOSSIL CENTERED CIRCLES. CLAY SEAMS, HIGHLY PLASTIC, AT 159.8, 161.6, 163.5. LIMESTONE LENS AT 182.6-182.9. COAL FRAGMENTS AT 130.,142.,175.,199. BONE FRAGMENTS 192.-194.8

184.8-207.5 HOLDERNESS MEMBER, WILLIAMS FORK FORMATION, MESA VERDE GROUP

194.8-196.3 SILTSTONE, SANDY. DARK GRAY-BLACK. SLIGHTLY CALCAREOUS. HARDNESS 6. (TRANSITIONAL CONTACT WITH LEWIS FM.)

196.3-200.1 COAL. VERY MINOR PYRITE. INTERBEDDED WITH SANDY SILTSTONE, 193.6-196.7. SAMPLE TAKEN.

200.1-200.3 SHALE. DARK GRAY-BLACK, CARBONACEOUS.

200.3-204.4 MUDSTONE. TURBULENT BEDDING WITH CARBONACEOUS FRAGMENTS. SOME SURFACE SLAKING UPON DRYING. HARDNESS 4-5.

204.4-207.5 SANDSTONE. LIGHT BUFF. FINE-GRAINED, PERMEABLE. NO APPARENT BEDDING. NON-CALCAREOUS. APPROX. 40 PERCENT OF GRAINS WHITE CHERT. HARDNESS 6. CORE MODE 5.

COMMENTS:

MUDSTONE.* EXPECT BLOCKY FRAGMENTS, 3 IN.-6', UPON BLASTING, WITH GENERATION OF HIGHLY PLASTIC MUD FROM FINES. EXPECT FRAGMENTS TO BE COHESIVE, FAIRLY RESISTANT TO WEATHERING.

NOTE: CORE LOGGED WITHIN 1 HOUR OF REMOVAL FROM HOLE. AFTER 3 MONTHS DRYING AND FREEZE-THAW WEATHERING MUDSTONE LOSES COHESION AND SLAKES TO FRAGS. .01-.3 IN. EXCEPT WHERE MUDSTONE GRADES TO LIMESTONE.

GEOLOGIC LOG OF HOLE NO DH4

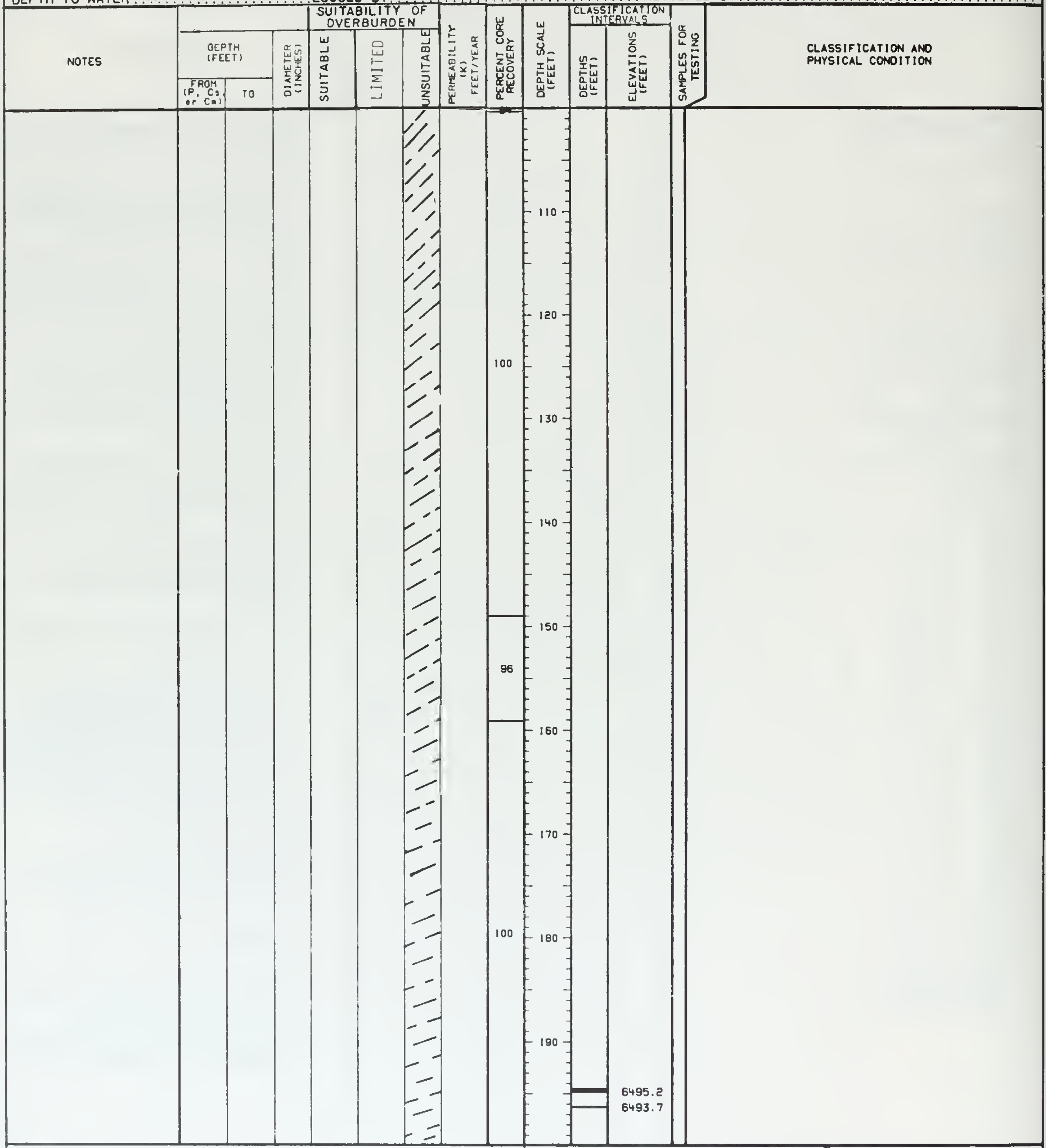
SHEET 2 OF 3

PROJECT EMRIA-BLM FEATURE FISH CREEK SITE AREA STATE COLORADO

LOCATION NE CORNER S21T5NR86W GROUND ELEV 6690. ANGLE FROM HORIZ 90.0 DOWN

BEGUN 9-1-76 FINISHED 9-6-76 DEPTH TO BEDROCK 17.5 TOTAL DEPTH 207.5 BEARING

DEPTH TO WATER 10.7 9-6-76 LOGGED BY J. TOMPKIN REVIEWED BY N. B. BENNETT



COMMENTS:

MUDSTONE.* EXPECT BLOCKY FRAGMENTS, 3 IN.-6', UPON BLASTING, WITH GENERATION OF HIGHLY PLASTIC MUD FROM FINES. EXPECT FRAGMENTS TO BE COHESIVE, FAIRLY RESISTANT TO WEATHERING.

NOTE: CORE LOGGED WITHIN 1 HOUR OF REMOVAL FROM HOLE. AFTER 3 MONTHS DRYING AND FREEZE-THAW WEATHERING MUDSTONE LOSES COHESION AND SLAKES TO FRAGS. .01-.3 IN. EXCEPT WHERE MUDSTONE GRADES TO LIMESTONE.

GEOLOGIC LOG OF HOLE NO DH4

SHEET 3 OF 3

PROJECT EMRIA-BLM FEATURE FISH CREEK SITE AREA STATE COLORADO
LOCATION NE CORNER S21T5NR86W GROUND ELEV. 6690 ANGLE FROM HORIZ 90.0 DOWN
BEGUN 9-1-76 FINISHED 9-6-76 DEPTH TO BEDROCK 17.5 TOTAL DEPTH 207.5 BEARING
DEPTH TO WATER 10.7 9-6-76 LOGGED BY J. TOMPKIN REVIEWED BY N. B. BENNETT

NOTES	DEPTH (FEET) FROM (P, Cs, or Cm)	DEPTH (FEET) TO	DIAMETER (INCHES)	SUITABILITY OF OVERBURDEN: SUITABLE	SUITABILITY OF OVERBURDEN: LIMITED	SUITABILITY OF OVERBURDEN: UNSUITABLE	PERMEABILITY (K) FEET/YEAR	PERCENT CORE RECOVERY	DEPTH SCALE (FEET)	CLASSIFICATION INTERVALS: DEPTHS (FEET)	CLASSIFICATION INTERVALS: ELEVATIONS (FEET)	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
						▨					6489.9		
						▨		100			6485.6		
						▨					6482.5		
									210				
									220				
									230				
									240				
									250				
									260				
									270				
									280				
									290				

COMMENTS:

MUDSTONE.• EXPECT BLOCKY FRAGMENTS, 3 IN.-6', UPON BLASTING, WITH GENERATION OF HIGHLY PLASTIC MUD FROM FINES. EXPECT FRAGMENTS TO BE COHESIVE, FAIRLY RESISTANT TO WEATHERING.

NOTE: CORE LOGGED WITHIN 1 HOUR OF REMOVAL FROM HOLE. AFTER 3 MONTHS DRYING AND FREEZE-THAW WEATHERING MUDSTONE LOSES COHESION AND SLAKES TO FRAGS. .01-.3 IN. EXCEPT WHERE MUDSTONE GRADES TO LIMESTONE.

GEOLOGIC LOG OF HOLE NO DH5

SHEET 1 OF 2

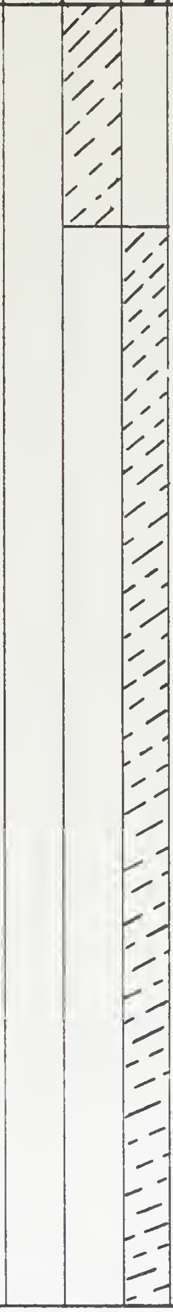
PROJECT EMRIA-BLM FEATURE FISH CREEK SITE AREA STATE COLORADO

LOCATION SW1/4NW1/4S21T5NR86W GROUND ELEV 6785 ANGLE FROM HORIZ 90.0 DOWN

BEGUN 9-6-76 FINISHED 9-9-76 DEPTH TO BEDROCK 17.2 TOTAL DEPTH 197.5 BEARING

DEPTH TO WATER 8.3 9-8-76 LOGGED BY J. TOMPKIN REVIEWED BY N. B. BENNETT

NOTES	DEPTH (FEET) FROM (P, Cs or Ca)	DEPTH (FEET) TO	DIAMETER (INCHES)	SUITABILITY OF OVERBURDEN: SUITABLE	SUITABILITY OF OVERBURDEN: LIMITED	SUITABILITY OF OVERBURDEN: UNSUITABLE	PERMEABILITY (K) FEET/YEAR	PERCENT CORE RECOVERY	DEPTH SCALE (FEET)	CLASSIFICATION INTERVALS: DEPTHS (FEET)	CLASSIFICATION INTERVALS: ELEVATIONS (FEET)	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION



NOTES

PURPOSE TO DETERMINE EXTENT AND NATURE OF OVERBURDEN ABOVE FISH CREEK COAL

DRILLED WITH CME 75 TRUCK MOUNTED DRILL RIG

HOLE TERMINATED WHEN NO COAL ENCOUNTERED AT DEPTH DEFINED AS MAXIMUM FOR ECONOMIC FEASIBILITY OF STRIP MINING

CORED WITH SPLIT SPOON SAMPLER TO 9.0 WITH NQ WIRELINE TD 197.5

AIR USED FOR DRILLIND 9.5-35.0 HOLE DRILLED WITH WATER 35.0-197.5

BOUND IN HOLE 9.5-20.5 INTERVAL

CASED WITH HOLLOW S[illegible] AUGER TO 24.5

WATER ENCOUNTERED AT 35.

CORE STUCK TO INNER BARBARREL WITH RESULTANT FRACTURING WHEN POUNDED OUT. CORE COHESIVE CAUSING DIFFICULTY IN BREAKING OFF WITH CATCHER.

PERFORATED PVC PIPE INSERTED IN HOLE TO 197.5

*ELEVATION TAKEN FROM MILNER QUADRANGLE

P- R TESTS

FROM	TO	BLOWS
0.0	0.5	4.0
0.5	1.0	8.
1.0	1.5	9.
1.5	2.0	15.
2.0	2.5	15.
2.5	3.0	17.
3.0	3.5	21.
3.5	4.0	21.
4.0	4.5	35.
4.5	5.0	32.
5.0	5.5	36.
5.5	6.0	50.
6.0	6.5	21.
6.5	7.0	34.
7.0	7.5	60.
7.5	8.0	23.
8.0	8.5	42.
8.5	9.0	84.

(P-R TESTS ARE FIELD APPROXIMATION: BLOW COUNTS TAKEN WHILE ADVANCING HOLE WITH SPLIT SPOON SAMPLER)

PERCENT CORE RECOVERY

100

55

60

92

97

90

96

100

97

100

DEPTH SCALE (FEET)

10

20

30

40

50

60

70

80

90

CLASSIFICATION INTERVALS

DEPTHS (FEET)	ELEVATIONS (FEET)
17.2	6767.8
38.3	6746.7

CLASSIFICATION AND PHYSICAL CONDITION

0.0-17.2 RESIDUAL SOIL DEPOSIT

0.0-17.2 CLAY. YELLOW- BROWN. GRAYER WITH DEPTH. SOIL DEVELOPMENT LIMITED TO UPPER 2 IN.. RED AND BLACK FE STAINING. DYPSUM COATINGS AND CRYSTALS, 6.0-10.5. (CH)

17.2-197.5 LEWIS FORMATION

17.2-38.3 MUDSTONE. MICA FLAKES. CALCAREOUS. 1 PERCENT CARBONACEOUS FRAGS. TEXTURE HOMOGENEOUS. COHESIVE. PARTINGS SMOOTH TO HACKLY. HARDNESS 5. CORE MODE .5'.

38.3-38.7 LIMESTONE. MED. GRAY. DENSE, COHESIVE. HARDNESS 6.

38.7-108.0 MUDSTONE. ROCK SIMILAR TO 17.2-38.3 INTERVAL. FOSSILS(INOCERAMUS, BRACHIOPODS, AMMONITES). SLICKENSIDED JOINT DIPPING 65 DEGREES. HARDNESS 5. CORE 1.5. AT 52.5, 77.2, 80.0, .2' LIMESTONE LAYERS. LT. GRAY, DIRTY. HARDNESS 7. AT 67.0-67.5 VERTICAL FISSILITY AND BRECCIATION.

108.0-150.0 MUDSTONE INTERBEDDED WITH LIMESTONE. LAMINAE .1-.5 IN. THICK. DARK GRAY WITH LIGHT GRAY LAMINAE. CALCAREOUS. FINELY DISSEMINATED CARBONACEOUS FRAGMENTS. LAMINAR BEDDING PLANES DIP 0-5 DEGREES FROM HORIZONTAL SOME SLUMP PLANES. ROCK MASS COHESIVE PARTINGS OCCUR ALONO SOME BEDDING PLANES WITH HAMMER BLOW. CORE MODE 1.5-5'.

150.0-179.5 MUDSTONE, JOINTED AND BRECCIATED. DARK GRAY, CALCAREOUS, WITH .3-.5 IN. LIMESTONE LAMINAE. SOME FOSSIL CONCENTRATIONS. SLICKENSIDED JOINTS DIPPING 50-65 DEGREES, FREQUENCY .2-1.0' AT 153.-167. CLAY LAYERS .3-.5 IN. THICK ALTERNATE WITH COHESIVE MUDSTONE LAYERS. HARDNESS VARIES FROM 4 IN CLAYEY SECTIONS TO 5 WHERE JOINTS ARE WIDELY SPACED.

179.5-197.5 MUDSTONE. CALCAREOUS. DARK GRAY. INTERBEDDED WITH LIGHT GRAY LIMESTONE LAMINAE, 50 PERCENT 1 IN. 50 PERCENT LESS THAN 1 IN.. SMALL AMOUNT CARBONACEOUS FRAGMENTS, 185-190. COHESIVE. CORE MODE 1.0-1.5

COMMENTS:

IF BLASTED, EXPECT MUDSTONE TO GENERATE FRAGMENTS FROM .5-6.0' EXCEPT FROM INTERVAL 150.0-179.5 WHERE ROCK FRAGMENTS WILL BE LESS THAN .5'. EXPECT GENERATION OF HIGHLY PLASTIC FINES IN ALL MUDSTONE INTERVALS.

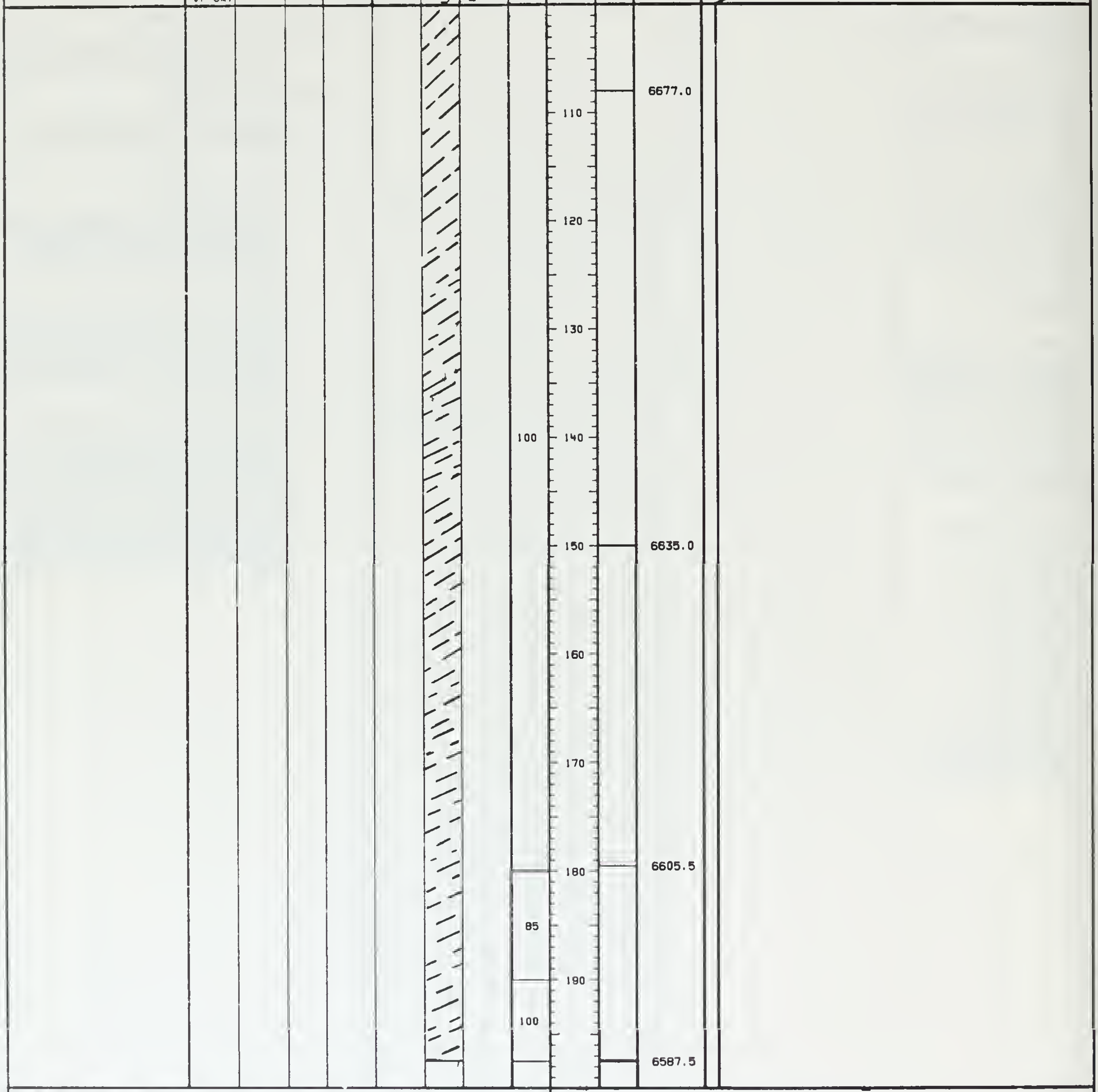
NOTE: CORE LOGGED WITHIN 1 HOUR AFTER REMOVAL FROM HOLE. AFTER 3 MONTHS DRYING AND FREEZE-THAW WEATHERINO MUDSTONE LOSES COHESION AND SLAKES TO FRAGS. .01-.3 IN. EXCEPT WHERE MUDSTONE GRADES TO LIMESTONE.

GEOLOGIC LOG OF HOLE NO DH5

SHEET 2 OF 2

PROJECT EMRIA-BLM FEATURE FISH CREEK SITE AREA STATE COLORADO
LOCATION SW1/4NW1/4S21T5NR86W GROUND ELEV 6785 ANGLE FROM HORIZ 90.0 DOWN
BEGUN 9-6-76 FINISHED 9-9-76 DEPTH TO BEDROCK 17.2 TOTAL DEPTH 197.5 BEARING
DEPTH TO WATER 8.3 9-8-76 LOGGED BY J. TOMPKIN REVIEWED BY N. B. BENNETT

NOTES	DEPTH (FEET) FROM (P, Cs, or Cm)	DEPTH (FEET) TO	DIAMETER (INCHES)	SUITABILITY OF OVERBURDEN: SUITABLE	SUITABILITY OF OVERBURDEN: LIMITED	SUITABILITY OF OVERBURDEN: UNSUITABLE	PERMEABILITY (K) FEET/YEAR	PERCENT CORE RECOVERY	DEPTH SCALE (FEET)	CLASSIFICATION INTERVALS: DEPTHS (FEET)	CLASSIFICATION INTERVALS: ELEVATIONS (FEET)	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION



COMMENTS:

IF BLASTED, EXPECT MUDSTONE TO GENERATE FRAGMENTS FROM .5-6.0' EXCEPT FROM INTERVAL 150.0-179.5 WHERE ROCK FRAGMENTS WILL BE LESS THAN .5'. EXPECT GENERATION OF HIGHLY PLASTIC FINES IN ALL MUDSTONE INTERVALS.

NOTE: CORE LOGGED WITHIN 1 HOUR AFTER REMOVAL FROM HOLE. AFTER 3 MONTHS DRYING AND FREEZE-THAW WEATHERING MUDSTONE LOSES COHESION AND SLAKES TO FRAGS. .01-.3 IN. EXCEPT WHERE MUDSTONE GRADES TO LIMESTONE.

GEOLOGIC LOG OF HOLE NO DH5

SHEET 2 OF 2

PROJECT EMRIA-BLM FEATURE FISH CREEK SITE AREA STATE COLORADO

LOCATION SW1/4NW1/4S21T5NR86W GROUND ELEV 6785 ANGLE FROM HORIZ 90.0 DOWN

BEGUN 9-6-76 FINISHED 8-8-76 DEPTH TO BEDROCK 17.2 TOTAL DEPTH 197.5 BEARING

DEPTH TO WATER 8.3 8-8-76 LOGGED BY J. TOMPKIN REVIEWED BY N. B. BENNETT

NOTES	DEPTH (FEET)		DIAMETER (INCHES)	SUITABILITY OF OVERBURDEN			PERMEABILITY (K) FEET/YEAR	PERCENT CORE RECOVERY	DEPTH SCALE (FEET)	CLASSIFICATION INTERVALS		SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
	FROM (P, Cs, or Cm)	TO		SUITABLE	LIMITED	UNSUITABLE				DEPTHS (FEET)	ELEVATIONS (FEET)		
											6677.0		
									110				
									120				
									130				
								100	140				
									150		6635.0		
									160				
									170				
									180		6605.5		
								85					
									190				
								100					
											6587.5		

COMMENTS:

IF BLASTED, EXPECT MUDSTONE TO GENERATE FRAGMENTS FROM .5-6.0' EXCEPT FROM INTERVAL 150.0-179.5 WHERE ROCK FRAGMENTS WILL BE LESS THAN .5'. EXPECT GENERATION OF HIGHLY PLASTIC FINES IN ALL MUDSTONE INTERVALS.

NOTE: CORE LOGGED WITHIN 1 HOUR AFTER REMOVAL FROM HOLE. AFTER 3 MONTHS DRYING AND FREEZE-THAW WEATHERING MUDSTONE LOSES COHESION AND SLAKES TO FRAGS. .01-.3 IN. EXCEPT WHERE MUDSTONE GRADES TO LIMESTONE.

FEATURE FISH CREEK SITE AREA SHEET 2 OF 2 HOLE NO DH5

APPENDIX B
Coal

ABSTRACT

The Fish Creek EMRIA site, an area of about 3.7 square miles is located in the southeastern part of the Yampa coal field on the steep to gently dipping beds of the Upper Cretaceous Williams Fork Formation.

The Fish Creek coal bed within 200 feet of the surface was evaluated by five core holes. Coal resources--measured, indicated, and inferred--within the site are 2,512,000 short tons, 7,970,000 short tons, and 507,000 short tons respectively.

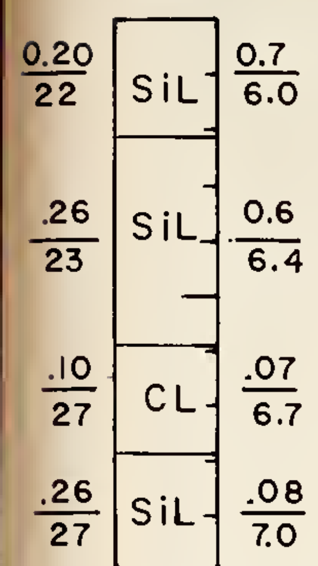
The coal has an apparent rank of bituminous C. The average Btu value of three core samples from the site on the as-received basis is 10,790, average ash content is 11.1 percent, and average sulfur content is 1.9 percent.

A comparison of the analyses of samples from the Fish Creek coal bed with other Rocky Mountain province coal sample analyses shows that nitrogen, total sulfur, and pyritic and organic sulfur contents are noticeably higher in the Fish Creek coal bed samples. A comparison of other element analyses shows that the Fish Creek coal bed is noticeably higher in As, Cr, F, Fe, Hg, and Sr, and noticeably lower in Th.

APPENDIX C

Soil

NO. ①

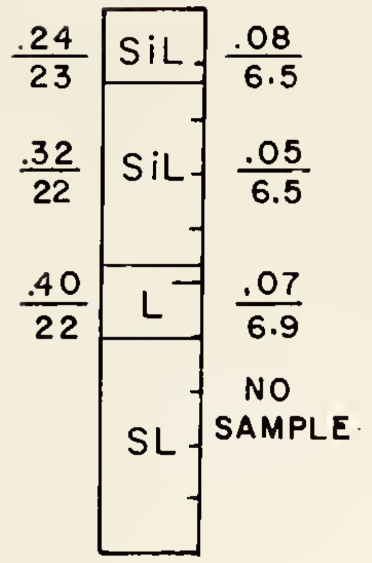


LOCATION: 400'N, 125'E SW COR. SEC. 20

PARENT MATERIAL: RESIDUAL SANDSTONE.

REMARKS: CULTIVATED GO-BACK 10-12% SLOPE, NORTH ASPECT.

NO. ②

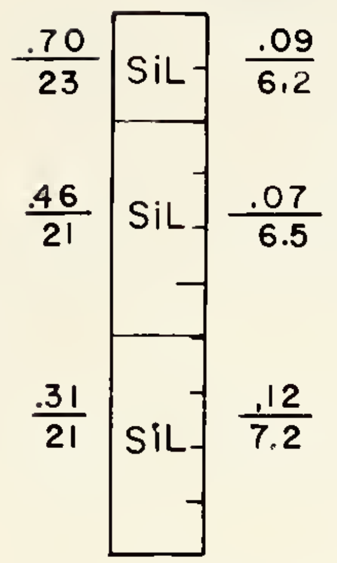


LOCATION: 350'W, 175'N OF S4 COR. SEC. 20

PARENT MATERIAL: REWORKED BROWN'S PARK.

REMARKS: CULTIVATED BROMEGRASS; SOME SANDSTONE FRAGMENTS (LESS THAN 10% BY VOLUME) BELOW 36 INCHES.

NO. ⑯

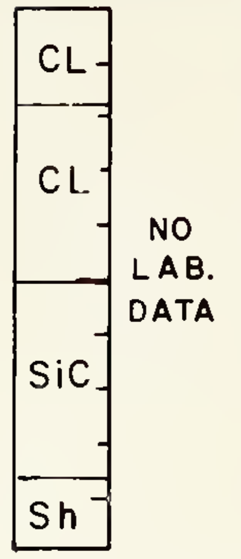


LOCATION: 1750'S, 125'E CENTER SEC. 20

PARENT MATERIAL: RESIDUAL SANDSTONE.

REMARKS: 20-40% BY VOLUME SANDSTONE FRAGMENTS 36-60 INCHES. IMMEDIATE AREA IS VERY VARIABLE AS TO DEPTH TO COARSE FRAGMENTS, CULTIVATED.

NO. ⑲

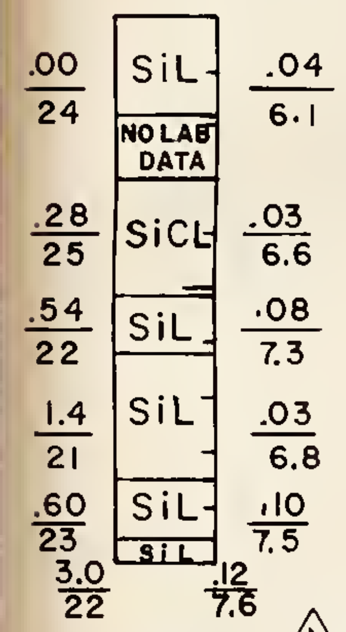


LOCATION: 1400'N, 1550'W SE COR. SEC. 20

PARENT MATERIAL: RESIDUAL SHALE AND SANDSTONE.

REMARKS: 30-52" YELLOW SILTY CLAY, 52"-56" GRAY SHALE, 15% SLOPE.

NO. 1

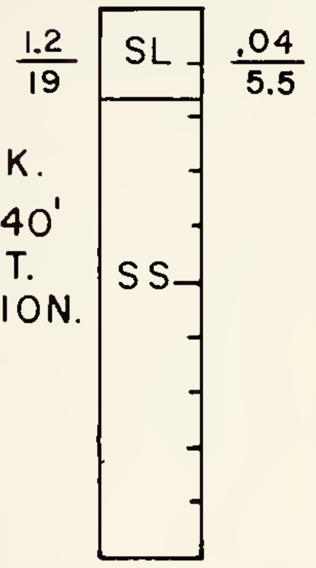


LOCATION: 1350'N, 350'E SW COR. SEC. 20

PARENT MATERIAL: REWORKED BROWN'S PARK.

REMARKS: ELEVATION 7040' 9% SLOPE, N-NE ASPECT. PD - PROFILE DESCRIPTION.

NO. ⑤

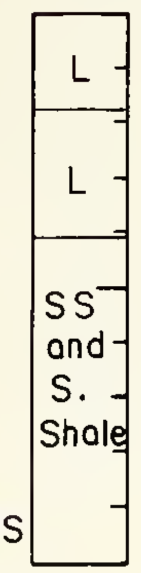


LOCATION: 350'S, 525'W W4 COR. SEC. 20

PARENT MATERIAL: RESIDUAL SANDSTONE.

REMARKS: 40% SANDSTONE FRAGMENTS ON SURFACE, MOST OF SURROUNDING AREA HAS MUCH LESS COARSE FRAGMENTS. NATIVE RANGE, EDGE OF DRAINAGE. SANDSTONE PROJECTED BELOW 18 INCHES

NO. ⑰

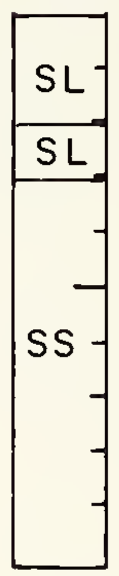


LOCATION: 1750'S, 125'W CENTER SEC. 20

PARENT MATERIAL: RESIDUAL SANDSTONE.

REMARKS: 12% SLOPE, FEW SANDSTONE FRAGMENTS FROM 10-24 INCHES. NO SAMPLES TAKEN.

NO. ⑳

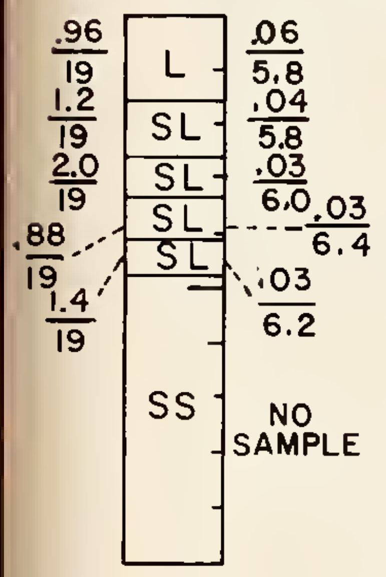


LOCATION: 2100'S, 2100'W NW COR. SEC. 20

PARENT MATERIAL: RESIDUAL SANDSTONE.

REMARKS: 50% BY VOLUME SANDSTONE FRAGMENTS FROM 12-18 INCHES. NO SAMPLES TAKEN.

NO. 1 DEEP HOLE #1

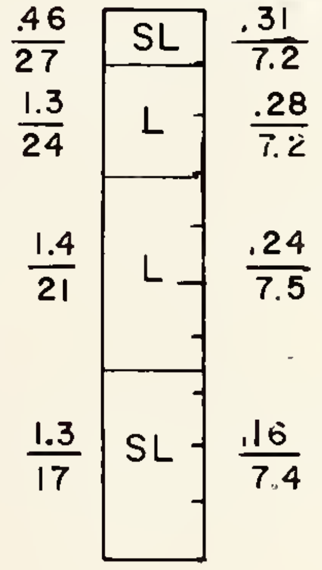


LOCATION: 200'E, 500'N OF W4 COR. SEC. 20

PARENT MATERIAL: RESIDUAL SANDSTONE.

REMARKS: 24-28" SOFT SANDSTONE, HARD SANDSTONE BELOW 28 INCHES, BROMEGRASS 1% SLOPE.

NO. ⑥

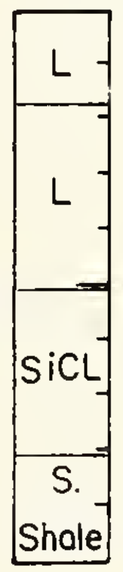


LOCATION: 300'S, 350'W NW $\frac{1}{16}$ COR. SEC. 20

PARENT MATERIAL: MIXED ALLUVIUM.

REMARKS: FLOODPLAIN, VERY STRATIFIED, MOTTLING FEW, DISTINCT AND MEDIUM FROM 40-60".

NO. ⑱

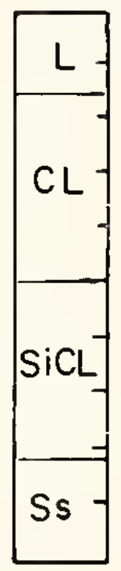


LOCATION: 300'S, 550'W CENTER SEC. 20

PARENT MATERIAL: RESIDUAL SANDSTONE.

REMARKS: NO SAMPLES TAKEN.

NO. ㊱

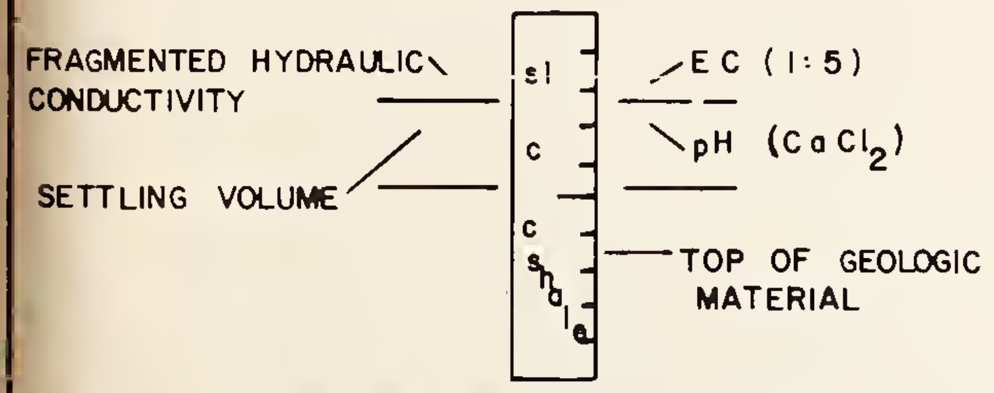


LOCATION: 1750'W, 150'N SE COR. SEC. 20

PARENT MATERIAL: RESIDUAL SANDSTONE.

REMARKS: NO SAMPLES TAKEN.

SOIL PROFILE KEY



SOIL PROFILE SYMBOLS

Cb	COBBLE	SiCL	SILTY CLAY LOAM
Gr	GRAVEL	SC	SANDY CLAY
S	SAND	C	CLAY
LS	LOAMY SAND	SiC	SILTY CLAY
SL	SANDY LOAM	Sh	SHALE
L	LOAM	Ss	SANDSTONE
SiL	SILT LOAM	Sis	SILTSTONE
SCL	SANDY CLAY LOAM	MUs	MUDSTONE
CL	CLAY LOAM		

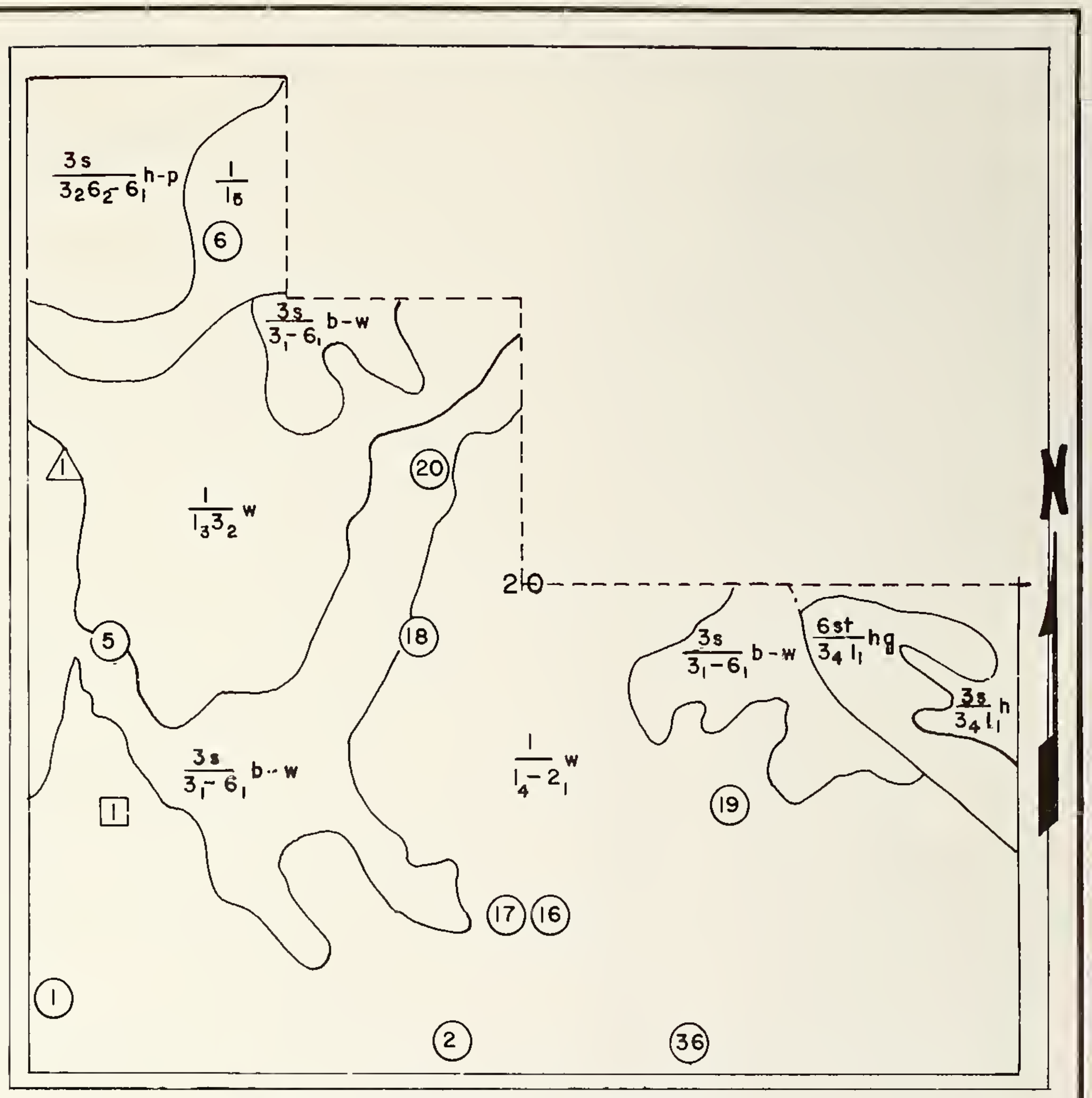
INFORMATIVE APPRAISALS

OVERBURDEN DEFICIENCIES

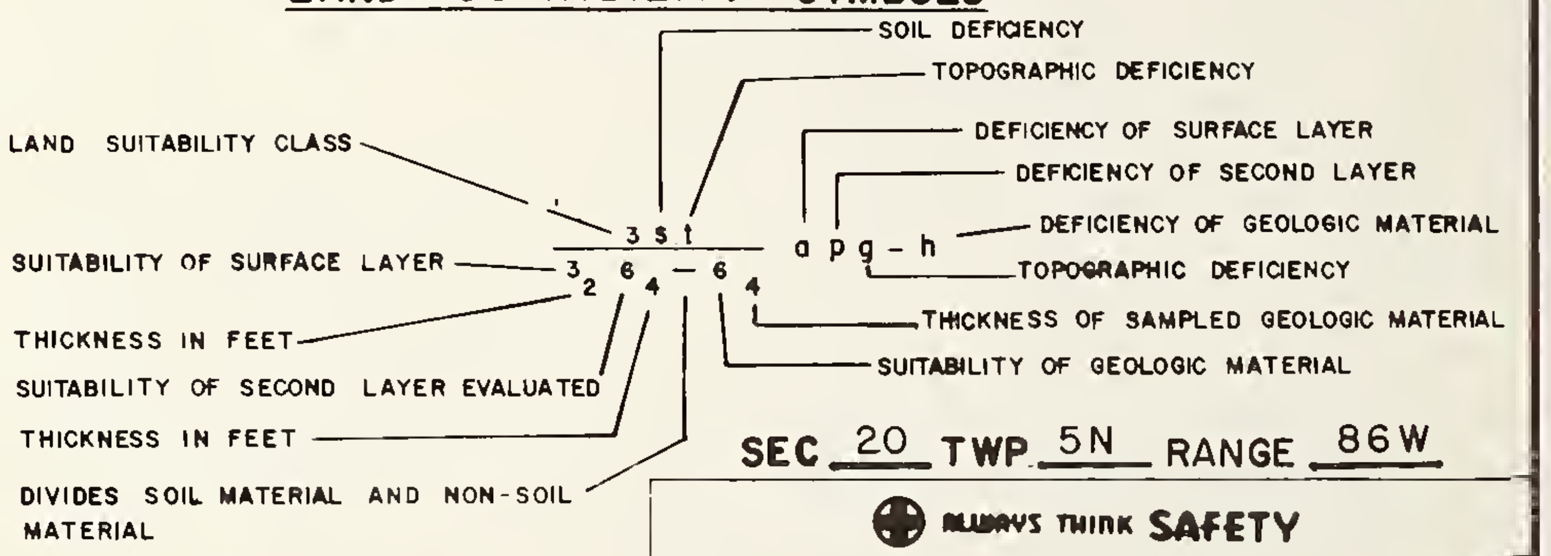
s	SALINITY
a	SODICITY
w	WEATHERABILITY
k	SHALLOW DEPTH TO COARSE SAND, GRAVEL, OR COBBLE
b	SHALLOW DEPTH TO RELATIVELY IMPERVIOUS SUBSTRATA
v	VERY COARSE TEXTURE (SANDS, LOAMY SANDS)
h	VERY FINE TEXTURE (CLAYS)
q	AVAILABLE MOISTURE CAPACITY
i	INFILTRATION
p	PERMEABILITY
x	STONINESS

TOPOGRAPHY DEFICIENCIES

g	SLOPE
c	SURFACE ROCKS
r	BEDROCK OUTCROPS



LAND SUITABILITY SYMBOLS


SOIL DEFICIENCY
TOPOGRAPHIC DEFICIENCY
DEFICIENCY OF SURFACE LAYER
DEFICIENCY OF SECOND LAYER
LAND SUITABILITY CLASS
3 s t
a p g - h
DEFICIENCY OF GEOLOGIC MATERIAL
SUITABILITY OF SURFACE LAYER
3₂ 6₄ — 6₄
TOPOGRAPHIC DEFICIENCY
THICKNESS OF SAMPLED GEOLOGIC MATERIAL
THICKNESS IN FEET
SUITABILITY OF GEOLOGIC MATERIAL
SUITABILITY OF SECOND LAYER EVALUATED
THICKNESS IN FEET
DIVIDES SOIL MATERIAL AND NON-SOIL MATERIAL

SEC 20 TWP 5N RANGE 86W

SCALE: 1"=1000'

ALWAYS THINK SAFETY

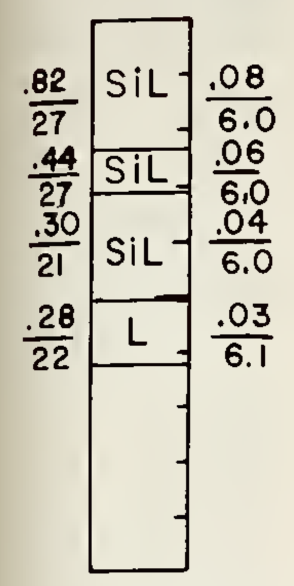
FISH CREEK STUDY SITE
LAND SUITABILITY
LANDS WERE CLASSED FOR THEIR SUITABILITY AS A SOURCE OF PLANTING MEDIA

DESIGNED ____ SUBMITTED A. SHINEMAN
DRAWN L. PETERSON RECOMMENDED ____
CHECKED T. CAPPELLUCCI APPROVED ____

LM REGION, DEN., COLO.

FIGURE C 1

NO. 2

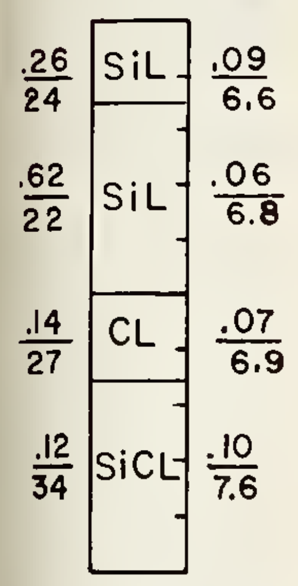


LOCATION: 200'S, 500'W
NE COR. SEC. 29

PARENT MATERIAL:
REWORKED BROWN'S PARK.

REMARKS: NORTHEAST
ASPECT 8-9% SLOPE,
SLOPING UPLAND RANGE.
PD - PROFILE DESCRIPTION.

NO. 3

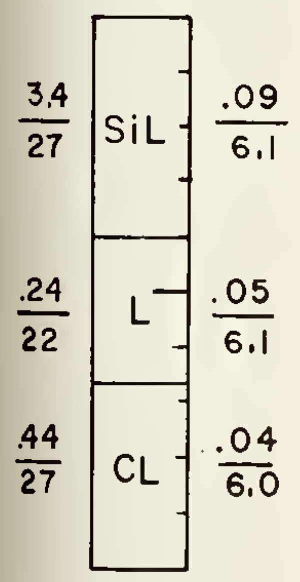


LOCATION: 1450'S, 2500'W
NE COR. SEC. 29

PARENT MATERIAL:
REWORKED BROWN'S PARK.

REMARKS: CULTIVATED,
10-12% SLOPE.

NO. 4

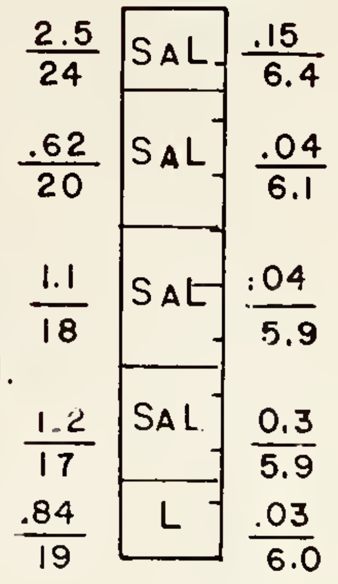


LOCATION: 1000'W, 150'S
NE COR. SEC. 29

PARENT MATERIAL:
REWORKED BROWN'S PARK.

REMARKS: IN AREA OF ASPEN
WITH GOOD GRASS COVER.

NO. 37



LOCATION: 990'E, 150'N
CENTER SEC. 29

PARENT MATERIAL:
COLLUVIUM

REMARKS: RANGE, WEAK
STRUCTURE THROUGHOUT.

NO.

NO.

NO.

NO.

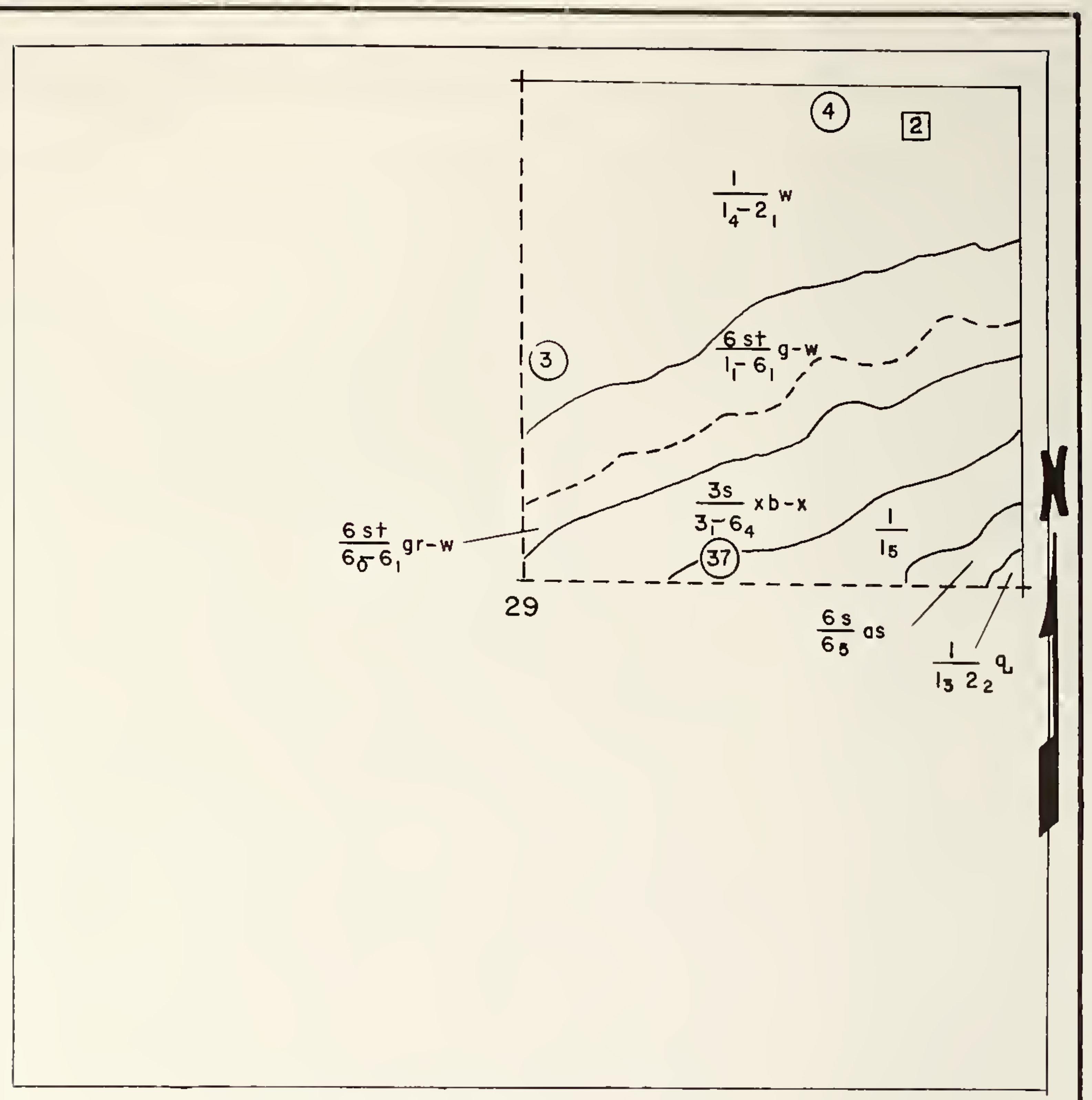
NO.

NO.

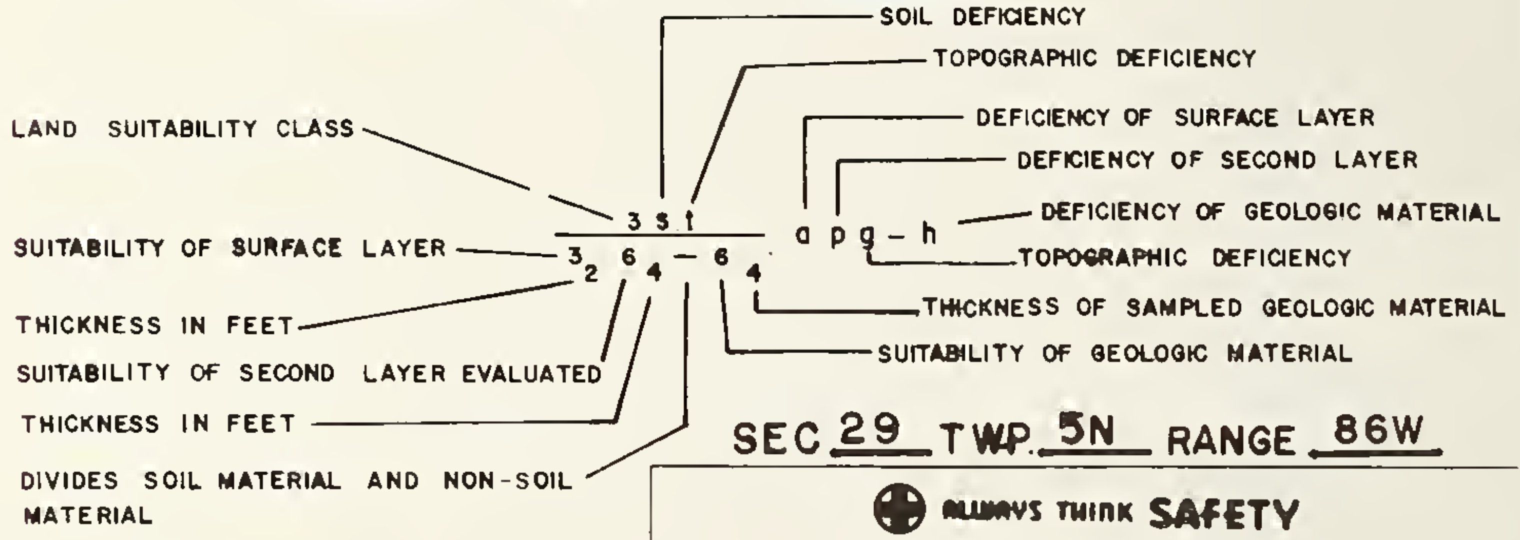
NO.

NO.

NO.



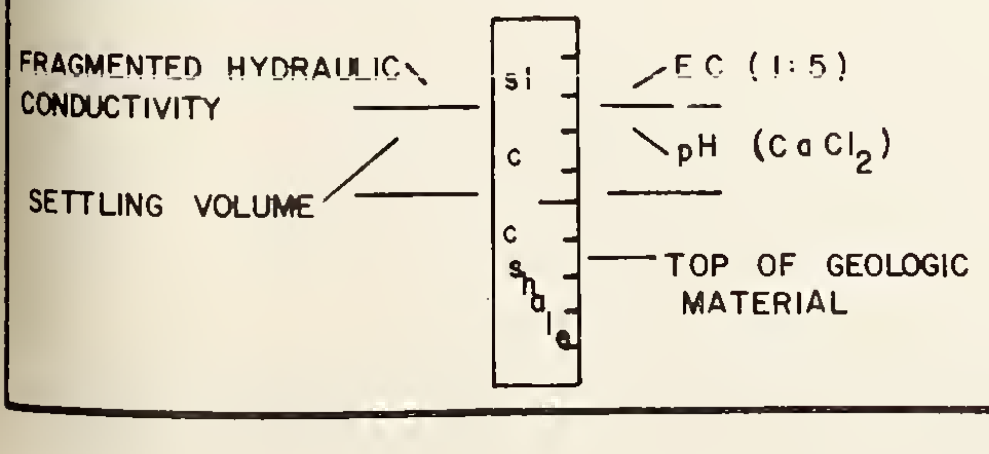
LAND SUITABILITY SYMBOLS



3 s t
3₂ 6₄ – 6 4
a p g – h
SOIL DEFICIENCY
TOPOGRAPHIC DEFICIENCY
LAND SUITABILITY CLASS
DEFICIENCY OF SURFACE LAYER
DEFICIENCY OF SECOND LAYER
DEFICIENCY OF GEOLOGIC MATERIAL
SUITABILITY OF SURFACE LAYER
TOPOGRAPHIC DEFICIENCY
THICKNESS IN FEET
THICKNESS OF SAMPLED GEOLOGIC MATERIAL
SUITABILITY OF SECOND LAYER EVALUATED
SUITABILITY OF GEOLOGIC MATERIAL
THICKNESS IN FEET
DIVIDES SOIL MATERIAL AND NON-SOIL MATERIAL

SCALE: 1"= 1000'

SOIL PROFILE KEY



SOIL PROFILE SYMBOLS

Cb	COBBLE	SiCL	SILTY CLAY LOAM
Gr	GRAVEL	S C	SANDY CLAY
S	SAND	C	CLAY
LS	LOAMY SAND	SiC	SILTY CLAY
SL	SANDY LOAM	Sh	SHALE
L	LOAM	Ss	SANDSTONE
SiL	SILT LOAM	Sis	SILTSTONE
SCL	SANDY CLAY LOAM	MUs	MUDSTONE
CL	CLAY LOAM		

INFORMATIVE APPRAISALS

OVERBURDEN DEFICIENCIES

s SALINITY
a SODICITY
w WEATHERABILITY
k SHALLOW DEPTH TO COARSE SAND, GRAVEL, OR COBBLE
b SHALLOW DEPTH TO RELATIVELY IMPERVIOUS SUBSTRATA
v VERY COARSE TEXTURE (SANDS, LOAMY SANDS)
h VERY FINE TEXTURE (CLAYS)
q AVAILABLE MOISTURE CAPACITY
i INFILTRATION
p PERMEABILITY
x STONINESS

TOPOGRAPHY DEFICIENCIES

g SLOPE
c SURFACE ROCKS
r BEDROCK OUTCROPS

SEC 29 TWP. 5N RANGE 86W

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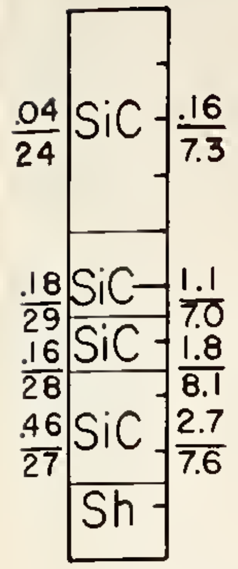
PLANTING MEDIA

DESIGNED ________ SUBMITTED A. SHINEMAN
DRAWN L. PETERSON RECOMMENDED ________
CHECKED T CAPPELLUCCI APPROVED ________

LM REGION, DEN., COLO. | FIGURE C2

NO. 2 DEEP HOLE #2

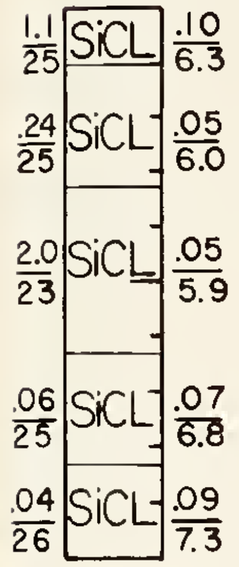


LOCATION: 2100'E, 100'N
SW COR. SEC. 21

PARENT MATERIAL: RESIDUAL SHALE (LEWIS)

REMARKS: SWALE, 5% SLOPE

NO. 4 DEEP HOLE # 4

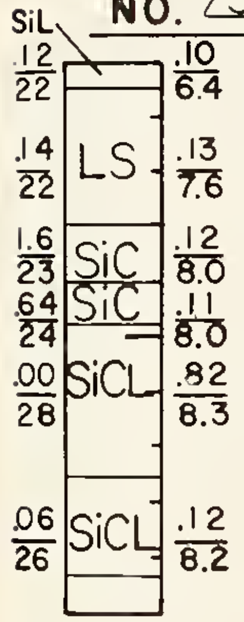


LOCATION: 100'W, 100'S
NE COR. SEC. 21

PARENT MATERIAL: RESIDUAL SHALE (LEWIS)

REMARKS: LOW BENCH, 3% SLOPE, CULTIVATED

NO. 5 DEEP HOLE # 5

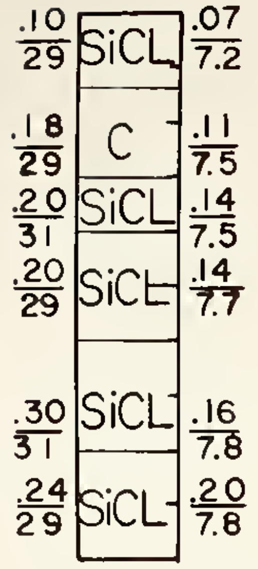


LOCATION: 2300'S, 600'E
NW COR. SEC. 21

PARENT MATERIAL: RESIDUAL SHALE (LEWIS)

REMARKS: RIDGE SIDE SLOPE. LOAMY SAND SURFACE NOT TYPICAL OF THIS AREA.

NO. 7

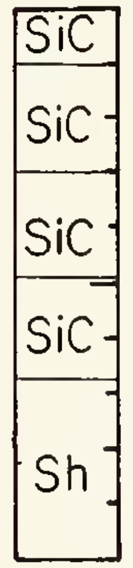


LOCATION: 1400'N, 125'E
SW COR. SEC. 21

PARENT MATERIAL: RESIDUAL SHALE (LEWIS)

REMARKS: FALLOW, RIDGETOP

NO. 8

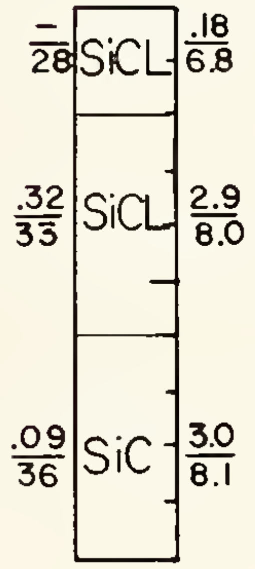


LOCATION: 1100'E, 2640'S
NW COR. SEC. 21

PARENT MATERIAL: RESIDUAL SHALE (LEWIS)

REMARKS: FALLOW, RIDGETOP

NO. 9

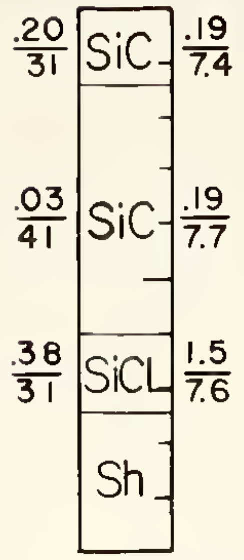


LOCATION: 400'S, 200'W
NW COR. SEC. 21

PARENT MATERIAL: RESIDUAL SHALE (LEWIS)

REMARKS: FALLOW, SALT CRYSTALS THROUGHOUT PROFILE, TERRACE POSITION, SOME RED SILTSTONE FRAGMENT 36-60 INCHES.

NO. 10

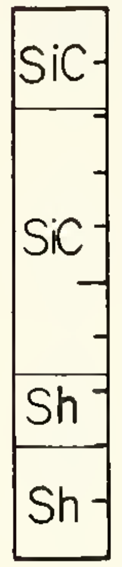


LOCATION: 2175'N, 1200'W
SE COR. SEC. 21

PARENT MATERIAL: RESIDUAL SHALE (LEWIS)

REMARKS: CULTIVATED, SOUTHASPECT, RIDGESIDE SLOPE

NO. 11

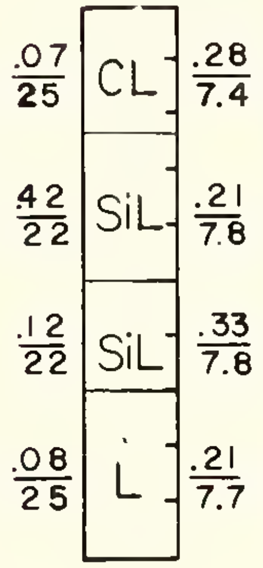


LOCATION: 1350'S, 1250'W
NE COR. SEC. 21

PARENT MATERIAL: RESIDUAL SHALE

REMARKS: SOUTH-EAST ASPECT CULTIVATED. WEATHERED SHALE FROM 40-48 INCHES. NO SAMPLES TAKEN

NO. 30

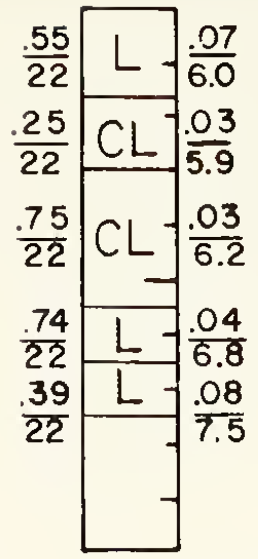


LOCATION: 550'W, 675'N
SE COR. SEC. 21

PARENT MATERIAL: MIXED ALLUVIUM

REMARKS: SEDGES, RUSHES WATERTABLE AT 54 INCHES. STRATIFIED

NO. 31

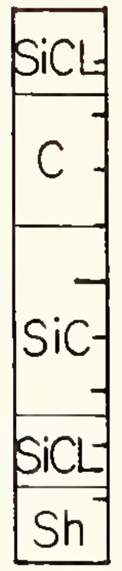


LOCATION: 250'N, 100'W OF SE COR. SEC. 21

PARENT MATERIAL: RESIDUAL SANDSTONE

REMARKS: IRR. ALFALFA

NO. 42

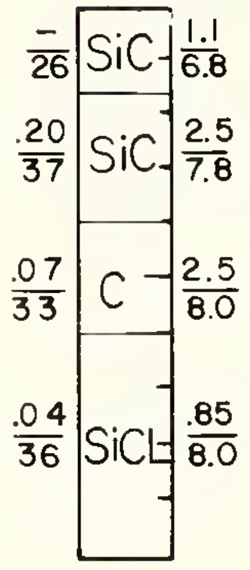


LOCATION: 250'N, 2500'W
SW COR. SEC. 21

PERCENT MATERIAL: RESIDUAL SHALE (LEWIS)

REMARKS: ISOLATED KNOLL, CULTIVATED. NO SAMPLES TAKEN

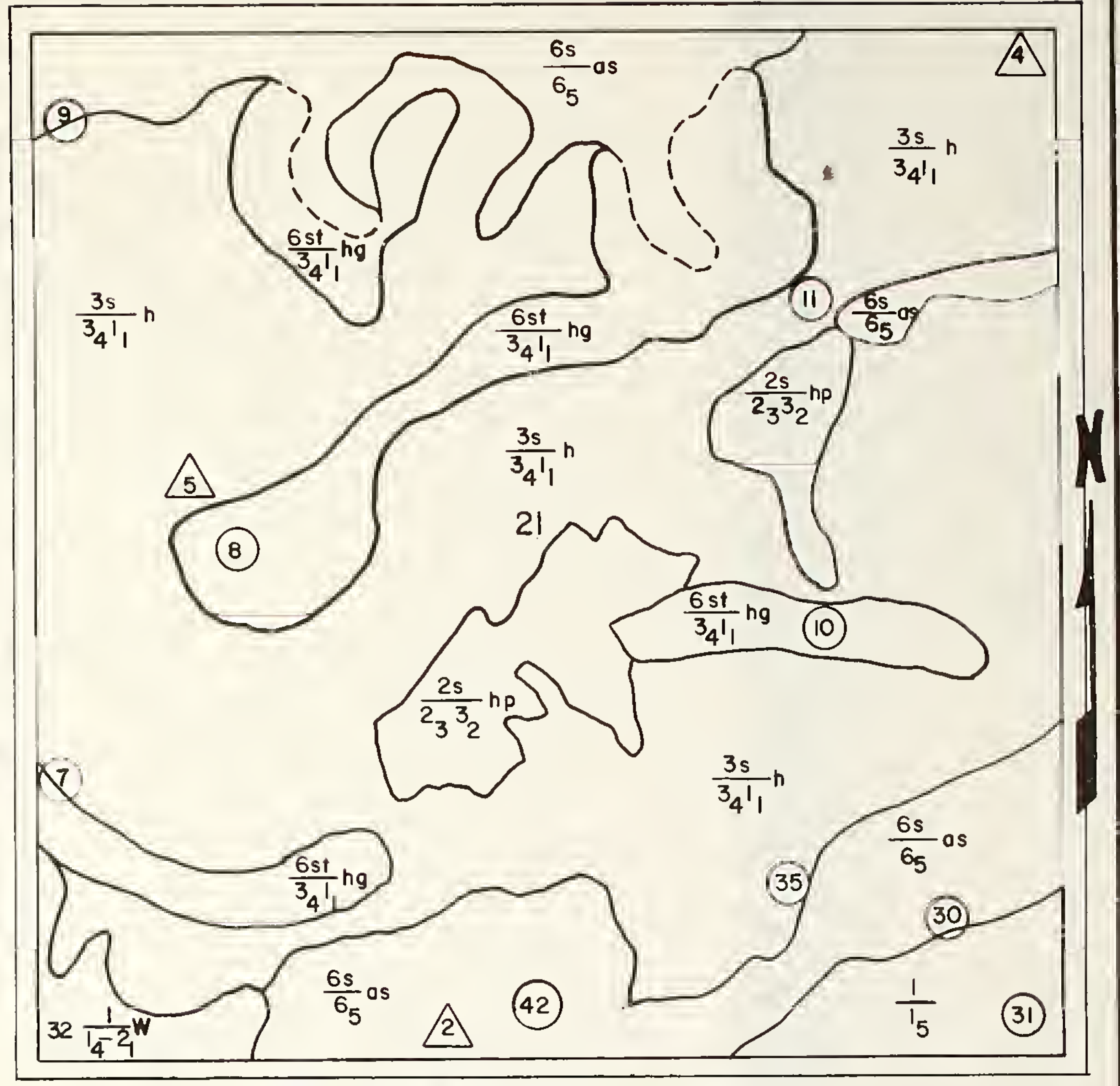
NO. 35



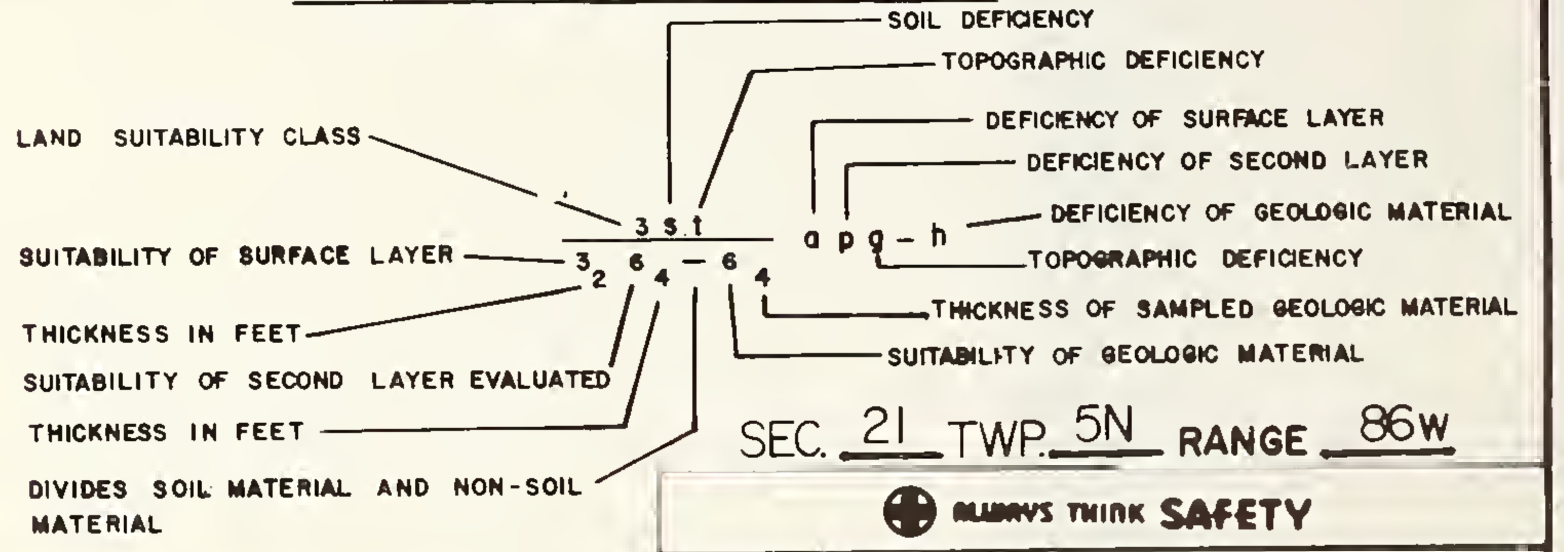
LOCATION: 900'N, 1300'W
SE COR. SEC. 21

PERCENT MATERIAL: RESIDUAL SHALE

REMARKS: ISOLATED KNOLL, CULTIVATED



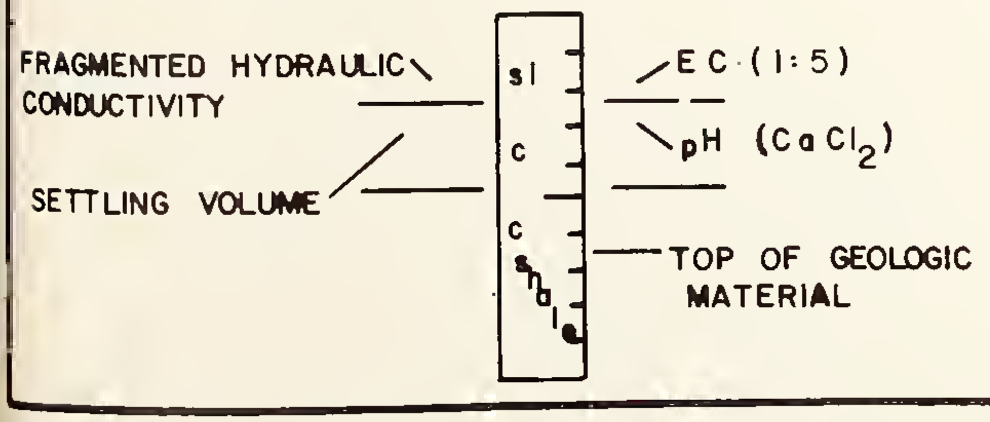
LAND SUITABILITY SYMBOLS



SOIL DEFICIENCY
TOPOGRAPHIC DEFICIENCY
LAND SUITABILITY CLASS
DEFICIENCY OF SURFACE LAYER
DEFICIENCY OF SECOND LAYER
DEFICIENCY OF GEOLOGIC MATERIAL
3 s t
a p g – h
SUITABILITY OF SURFACE LAYER
3₂ 6₄ — 6 4
TOPOGRAPHIC DEFICIENCY
THICKNESS OF SAMPLED GEOLOGIC MATERIAL
THICKNESS IN FEET
SUITABILITY OF GEOLOGIC MATERIAL
SUITABILITY OF SECOND LAYER EVALUATED
THICKNESS IN FEET
DIVIDES SOIL MATERIAL AND NON-SOIL MATERIAL

SEC. 21 TWP. 5N RANGE 86W

SOIL PROFILE KEY



SOIL PROFILE SYMBOLS

Cb	COBBLE	SiCL	SILTY CLAY LOAM
Gr	GRAVEL	S C	SANDY CLAY
S	SAND	C	CLAY
LS	LOAMY SAND	SiC	SILTY CLAY
SL	SANDY LOAM	Sh	SHALE
L	LOAM	Ss	SANDSTONE
SiL	SILT LOAM	Sis	SILTSTONE
SCL	SANDY CLAY LOAM	MUs	MUDSTONE
CL	CLAY LOAM		

INFORMATIVE APPRAISALS

OVERBURDEN DEFICIENCIES

s SALINITY
a SODICITY
w WEATHERABILITY
k SHALLOW DEPTH TO COARSE SAND, GRAVEL, OR COBBLE
b SHALLOW DEPTH TO RELATIVELY IMPERVIOUS SUBSTRATA
v VERY COARSE TEXTURE (SANDS, LOAMY SANDS)
h VERY FINE TEXTURE (CLAYS)
q AVAILABLE MOISTURE CAPACITY
i INFILTRATION
p PERMEABILITY
x STONINESS

TOPOGRAPHY DEFICIENCIES

g SLOPE
c SURFACE ROCKS
r BEDROCK OUTCROPS

SCALE: 1" = 1000'

ALWAYS THINK SAFETY

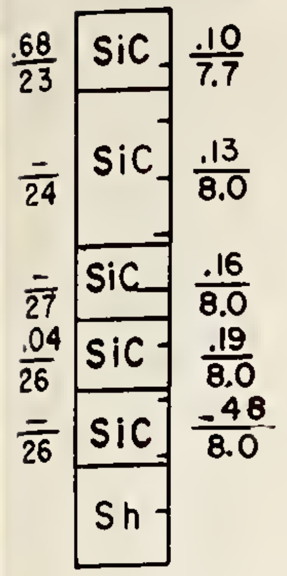
FISH CREEK STUDY SITE

LAND SUITABILITY
LANDS WERE CLASSED FOR THEIR SUITABILITY AS A SOURCE OF PLANTING MEDIA

DESIGNED ______ SUBMITTED A. SHINEMAN
DRAWN L. PETERSON RECOMMENDED ______
CHECKED T. CAPPELLUCCI APPROVED ______

LM REGION, DEN., COLO. | FIGURE C 3

NO. 5

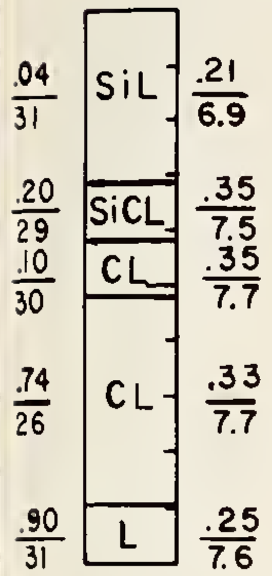


LOCATION: 2500'E, 200'S
NW COR. SEC. 22

PARENT MATERIAL: RESIDUAL SHALE (LEWIS).

REMARKS: CULTIVATED, LOW FAN 1% SLOPE. PD-PROFILE DESCRIPTION.

NO. 7

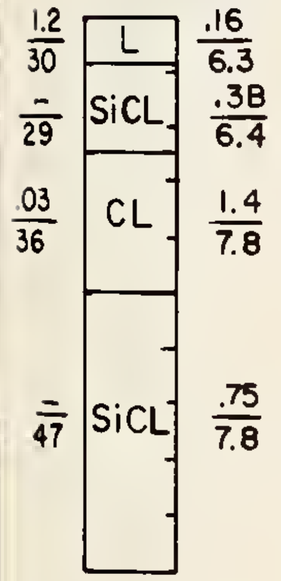


LOCATION: 2000'N, 250'E
SW COR. SEC. 22

PARENT MATERIAL: MIXED ALLUVIUM.

REMARKS: FLOODPLAIN PD-PROFILE DESCRIPTION.

NO. 12



LOCATION: 250'N, 50'W
CENTER SEC. 22

PARENT MATERIAL: RESIDUAL SHALE.

REMARKS: 0-4" MEDIUM MODERATE SUBANGULAR BLOCKY TO MEDIUM MODERATE GRANULAR.

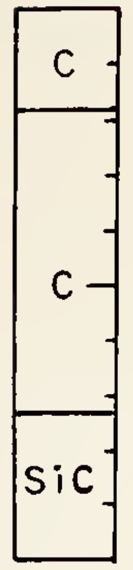
4-14" FINE STRONG ANGULAR BLOCKY

14-30" MASSIVE

30-60" MASSIVE

WATER TABLE AT 54"

NO. 13

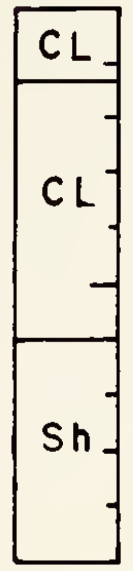


LOCATION: 2300'E, 750'S
NW COR. SEC. 22

PARENT MATERIAL: RESIDUAL SHALE (LEWIS)

REMARKS: WEST ASPECT, CULTIVATED, VERY HARD CONSISTENCE.
NO SAMPLES TAKEN.

NO. 14

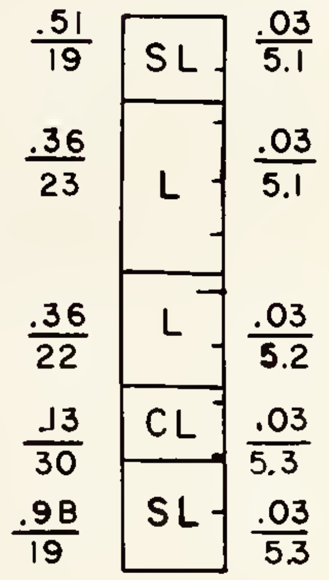


LOCATION: 2375'E, 1550'S
NW COR. SEC. 22

PARENT MATERIAL: RESIDUAL SHALE (LEWIS)

REMARKS: CULTIVATED. NO SAMPLES TAKEN.

NO. 27

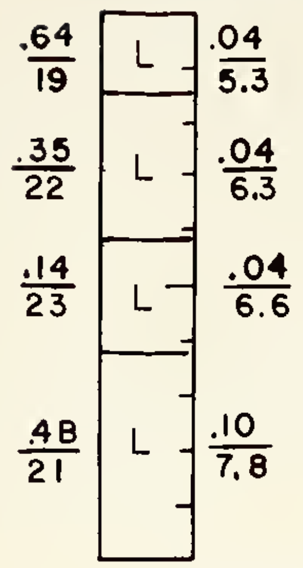


LOCATION: 2250'E, 400'N
SW COR. SEC. 22

PARENT MATERIAL: RESIDUAL SANDSTONE.

REMARKS: IRRIGATED ALFALFA.

NO. 28

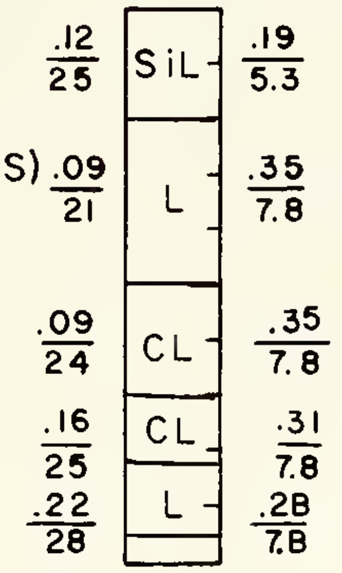


LOCATION: 1800'E, 1850'N
SW COR. SEC. 22

PARENT MATERIAL: RESIDUAL SANDSTONE.

REMARKS: LOW TERRACE, STRONG ANGULAR BLOCKY FROM 8-38".

NO. 29



LOCATION: 1200'E, 2150'N
SW COR. SEC. 22

PARENT MATERIAL: MIXED ALLUVIUM.

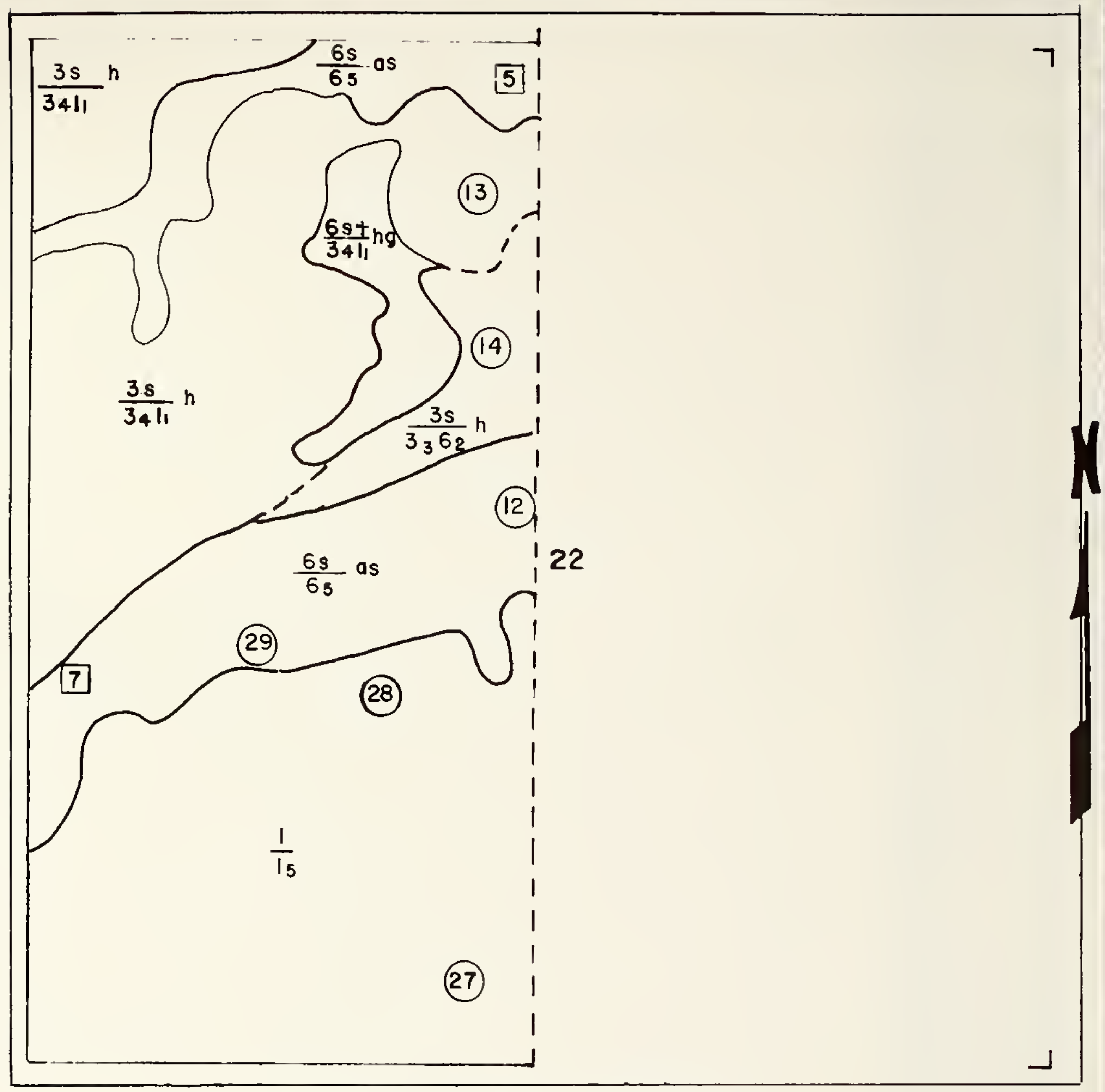
REMARKS: WATER TABLE AT 56 INCHES. SOME SMALL AREAS OF SALT CRUSTS ON SURFACE.

NO.

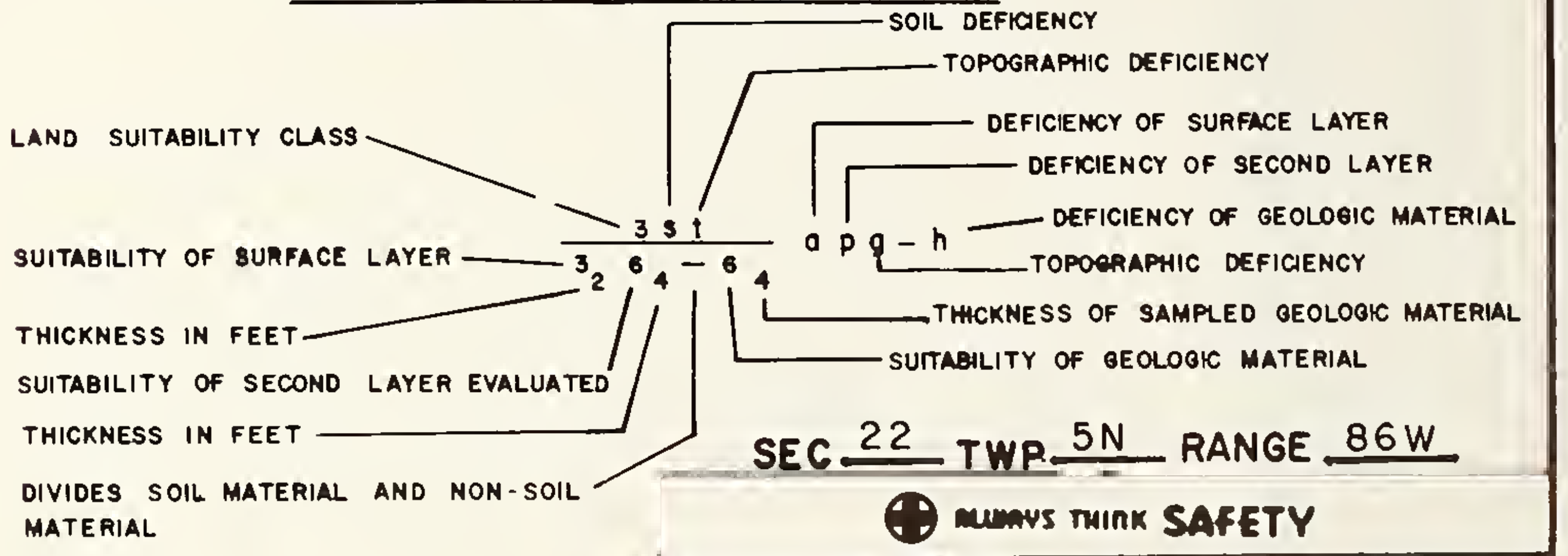
NO.

NO.

NO.

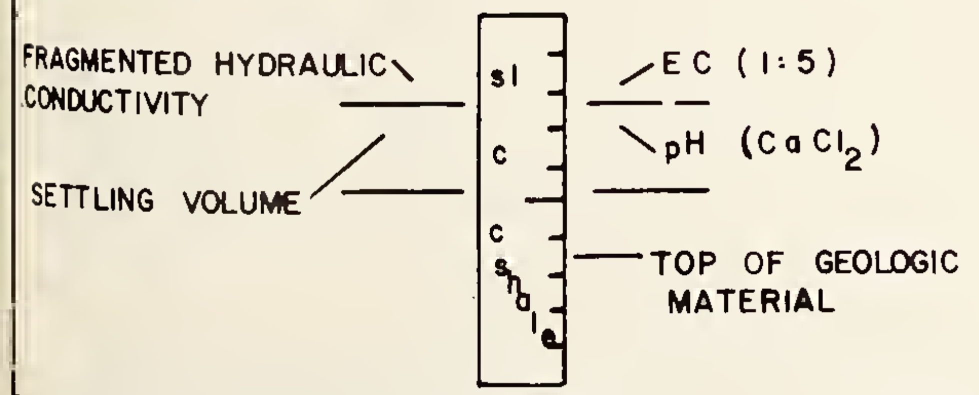


LAND SUITABILITY SYMBOLS


SOIL DEFICIENCY
TOPOGRAPHIC DEFICIENCY
DEFICIENCY OF SURFACE LAYER
DEFICIENCY OF SECOND LAYER
DEFICIENCY OF GEOLOGIC MATERIAL
TOPOGRAPHIC DEFICIENCY
THICKNESS OF SAMPLED GEOLOGIC MATERIAL
SUITABILITY OF GEOLOGIC MATERIAL
LAND SUITABILITY CLASS
SUITABILITY OF SURFACE LAYER
THICKNESS IN FEET
SUITABILITY OF SECOND LAYER EVALUATED
THICKNESS IN FEET
DIVIDES SOIL MATERIAL AND NON-SOIL MATERIAL
3 s t
3₂ 6₄ – 6₄
a p g – h

SEC 22 TWP 5N RANGE 86W

SOIL PROFILE KEY



SOIL PROFILE SYMBOLS

Cb	COBBLE	SiCL	SILTY CLAY LOAM
Gr	GRAVEL	SC	SANDY CLAY
S	SAND	C	CLAY
LS	LOAMY SAND	SiC	SILTY CLAY
SL	SANDY LOAM	Sh	SHALE
L	LOAM	Ss	SANDSTONE
SiL	SILT LOAM	Sis	SILTSTONE
SCL	SANDY CLAY LOAM	MUs	MUDSTONE
CL	CLAY LOAM		

INFORMATIVE APPRAISALS

OVERBURDEN DEFICIENCIES

s	SALINITY
a	SODICITY
w	WEATHERABILITY
k	SHALLOW DEPTH TO COARSE SAND, GRAVEL, OR COBBLE
b	SHALLOW DEPTH TO RELATIVELY IMPERVIOUS SUBSTRATA
v	VERY COARSE TEXTURE (SANDS, LOAMY SANDS)
h	VERY FINE TEXTURE (CLAYS)
q	AVAILABLE MOISTURE CAPACITY
i	INFILTRATION
p	PERMEABILITY
x	STONINESS

TOPOGRAPHY DEFICIENCIES

g	SLOPE
c	SURFACE ROCKS
r	BEDROCK OUTCROPS

SCALE: 1"= 1000'

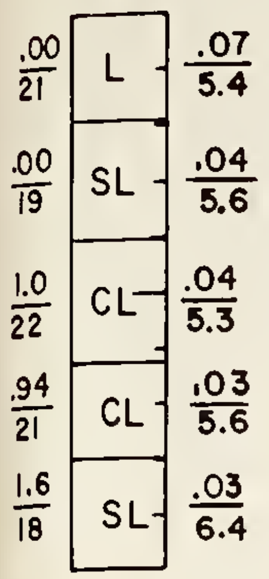
ALWAYS THINK SAFETY

FISH CREEK STUDY SITE
LAND SUITABILITY
LANDS WERE CLASSED FOR THEIR SUITABILITY AS A SOURCE OF PLANTING MEDIA

DESIGNED ____ SUBMITTED A. SHINEMAN
DRAWN L. PETERSON RECOMMENDED ____
CHECKED T. CAPPELLUCCI APPROVED ____

LM REGION, DEN., COLO.
FIGURE C 4

NO. △3 DEEPHOLE #3

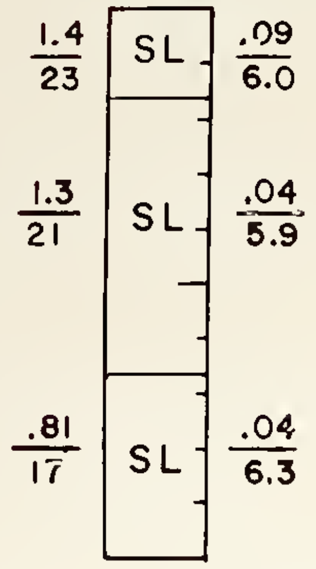


LOCATION: 2450'E, 300'S
NW COR. SEC. 27

PARENT MATERIAL:
RESIDUAL SANDSTONE.

REMARKS: HYDRAULIC CONDUCTIVITY FOR TOP TWO LAYERS IS NOT REPRESENTATIVE FOR SOILS MAPPED IN THIS DELINEATION
IRRIGATED ALFALFA.
2% SLOPE.

NO. ⑮

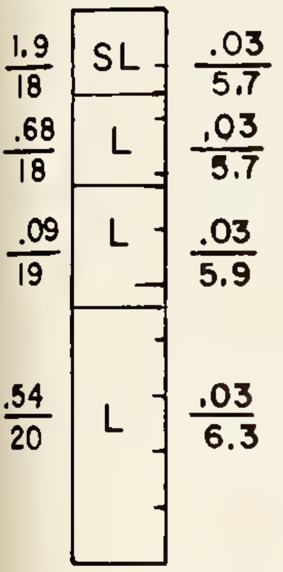


LOCATION: 1350', 1150'N
SW COR. SEC. 27

NO.

NO.

NO. 4

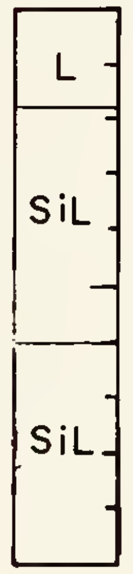


LOCATION: 2000'E, 1275'N
SW COR. SEC. 27

PARENT MATERIAL:
RESIDUAL SANDSTONE

REMARKS: ROUNDED HILL CREST, PD-PROFILE DESCRIPTION.

NO. ㊵



LOCATION: 550'E, 1450'S
NW COR. SEC. 27

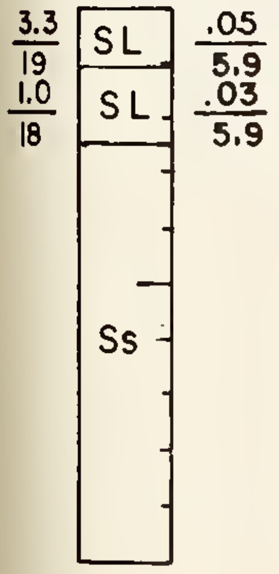
PARENT MATERIAL: RESIDUAL SANDSTONE.

REMARKS: IRRIGATED PASTURE 10% SLOPE.
NO SAMPLES TAKEN.

NO.

NO.

NO. 6



LOCATION: 100'E, 200'N
SW COR. SEC. 27

PARENT MATERIAL: AEOLIAN SANDS.

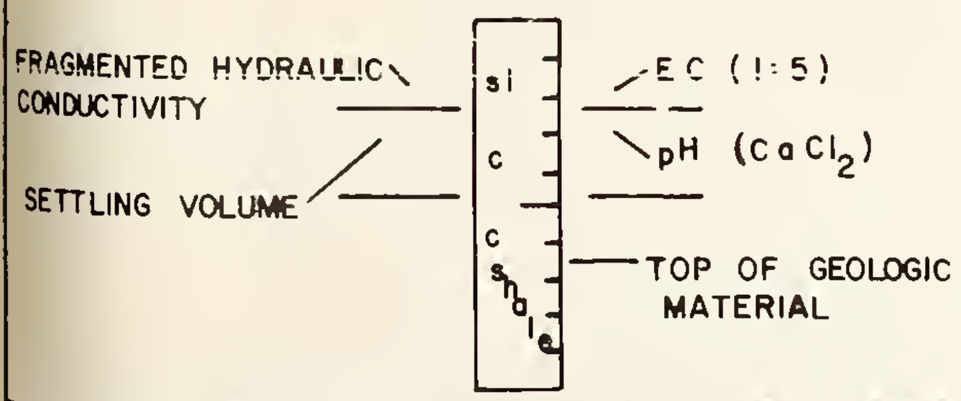
REMARKS: 17% SLOPE, NORTHEAST ASPECT.
PD-PROFILE DESCRIPTION.

NO.

NO.

NO.

SOIL PROFILE KEY



SOIL PROFILE SYMBOLS

Cb	COBBLE	SiCL	SILTY CLAY LOAM
Gr	GRAVEL	SC	SANDY CLAY
S	SAND	C	CLAY
LS	LOAMY SAND	SiC	SILTY CLAY
SL	SANDY LOAM	Sh	SHALE
L	LOAM	Ss	SANDSTONE
SiL	SILT LOAM	Sis	SILTSTONE
SCL	SANDY CLAY LOAM	MUs	MUDSTONE
CL	CLAY LOAM		

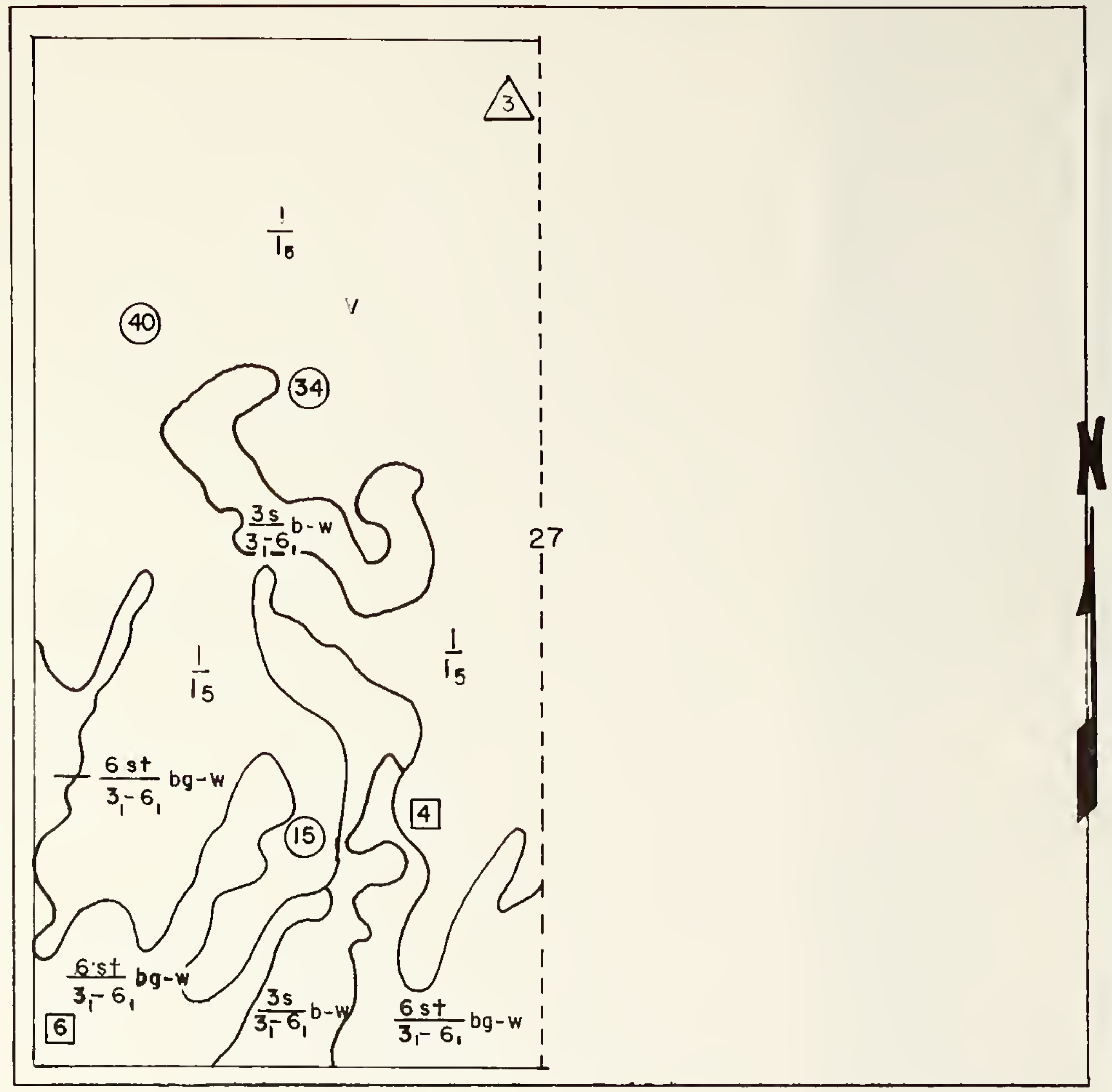
INFORMATIVE APPRAISALS

OVERBURDEN DEFICIENCIES

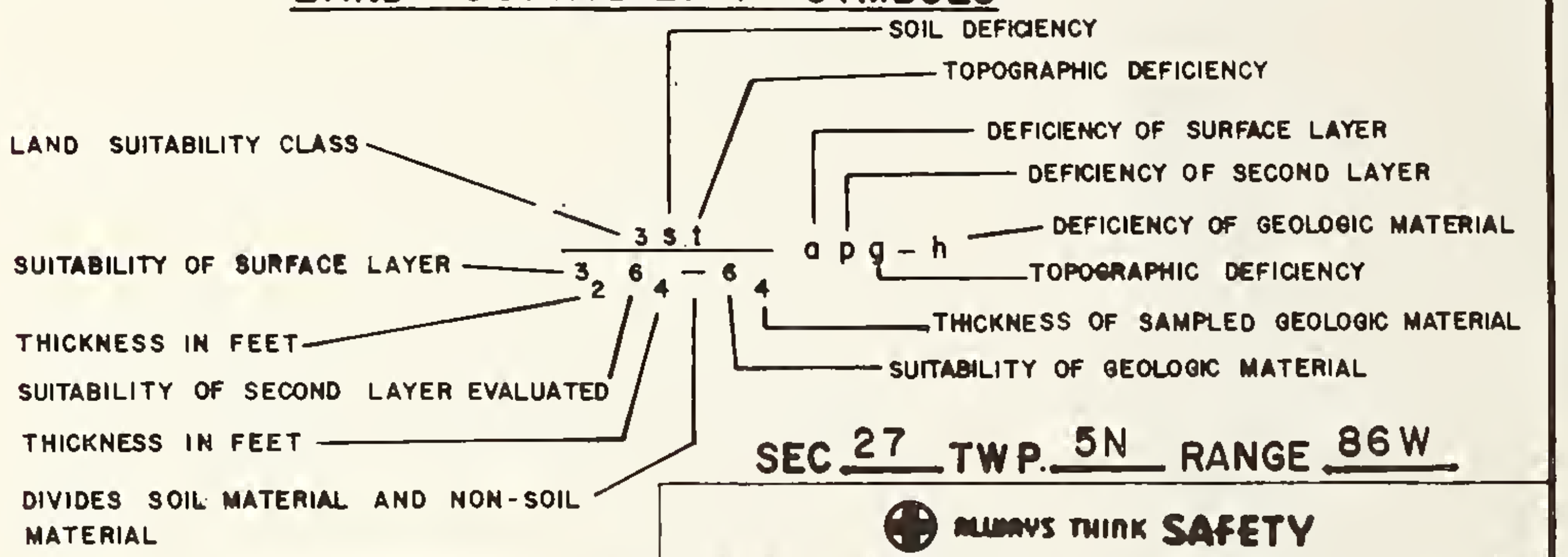
s	SALINITY
a	SODICITY
w	WEATHERABILITY
k	SHALLOW DEPTH TO COARSE SAND, GRAVEL, OR COBBLE
b	SHALLOW DEPTH TO RELATIVELY IMPERVIOUS SUBSTRATA
v	VERY COARSE TEXTURE (SANDS, LOAMY SANDS)
h	VERY FINE TEXTURE (CLAYS)
q	AVAILABLE MOISTURE CAPACITY
i	INFILTRATION
p	PERMEABILITY
x	STONINESS

TOPOGRAPHY DEFICIENCIES

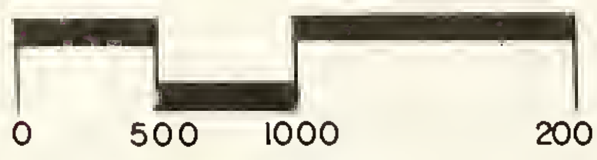
g	SLOPE
c	SURFACE ROCKS
r	BEDROCK OUTCROPS



LAND SUITABILITY SYMBOLS


SOIL DEFICIENCY
TOPOGRAPHIC DEFICIENCY
LAND SUITABILITY CLASS
DEFICIENCY OF SURFACE LAYER
DEFICIENCY OF SECOND LAYER
3 s t
a p g – h
DEFICIENCY OF GEOLOGIC MATERIAL
SUITABILITY OF SURFACE LAYER
3 2 6 4 – 6 4
TOPOGRAPHIC DEFICIENCY
THICKNESS IN FEET
THICKNESS OF SAMPLED GEOLOGIC MATERIAL
SUITABILITY OF SECOND LAYER EVALUATED
SUITABILITY OF GEOLOGIC MATERIAL
THICKNESS IN FEET
DIVIDES SOIL MATERIAL AND NON-SOIL MATERIAL

SEC 27 TWP. 5N RANGE 86W



SCALE 1" = 1000'

ALWAYS THINK SAFETY

FISH CREEK STUDY SITE

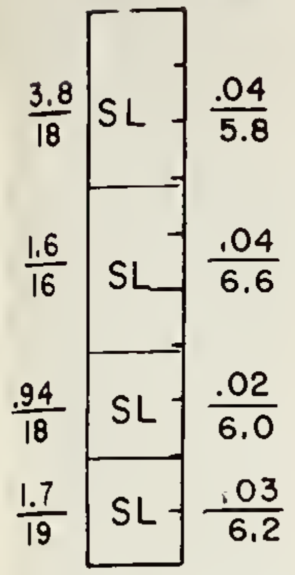
LAND SUITABILITY

LANDS WERE CLASSED FOR THEIR SUITABILITY AS A SOURCE OF PLANTING MEDIA

DESIGNED _____ SUBMITTED A. SHINEMAN
DRAWN L. PETERSON RECOMMENDED _____
CHECKED T. CAPPELLUCCI APPROVED _____

LM REGION, DEN., COLO. | FIGURE C5

NO. 3

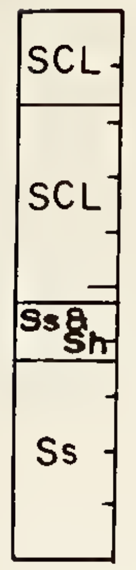


LOCATION: 1850'S, 2000'W
NE COR. SEC. 28

PARENT MATERIAL: RESIDUAL SANDSTONE.

REMARKS: VEGETATION-SAGE.
PD-PROFILE DESCRIPTION.

NO. ㉓

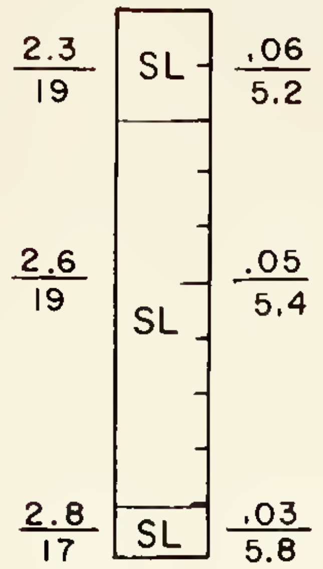


LOCATION: 2400'S, 100'W
NE COR. SEC. 28

PARENT MATERIAL: RESIDUAL SANDSTONE.

REMARKS: IRRIGATED ALFALFA, SMALL DRAINAGE AREA. NO SAMPLES TAKEN.

NO. ㉖



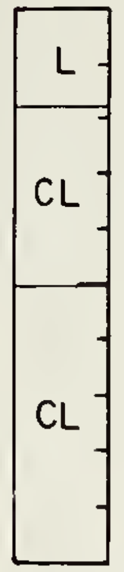
LOCATION: 2050'E, 2000'S
NW COR. SEC. 28

PARENT MATERIAL: AEOLIAN SANDS.

REMARKS: THESE ARE VERY COARSE SANDY LOAMS HAVING LESS THAN 8% CLAY.

NO.

NO. ㉑



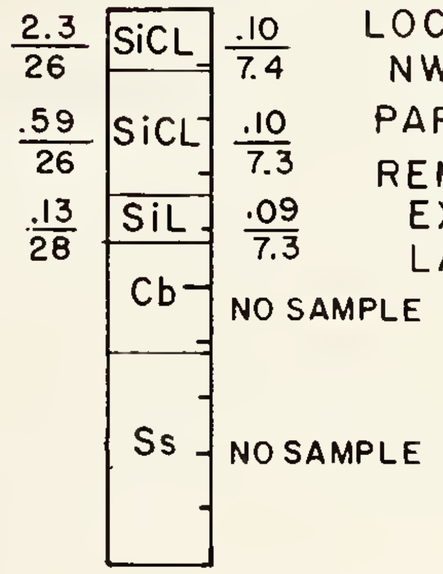
LOCATION: 1700'S, 450'E
NW COR. SEC. 28

PARENT MATERIAL: COLLUVIUM

REMARKS: 15% SLOPE, SAGEBRUSH AND NATIVE GRASSES.

NO SAMPLES TAKEN.

NO. ㉔



LOCATION: 2500'S, 1100'E
NW COR. SEC. 28

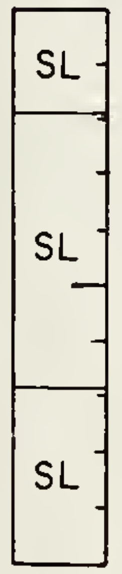
PARENT MATERIAL: COLLUVIUM

REMARKS: 30% SLOPE, IN EXCESS OF 50% BY VOLUME LARGE COBBLE FROM 26-36".

NO.

NO.

NO. ㉒

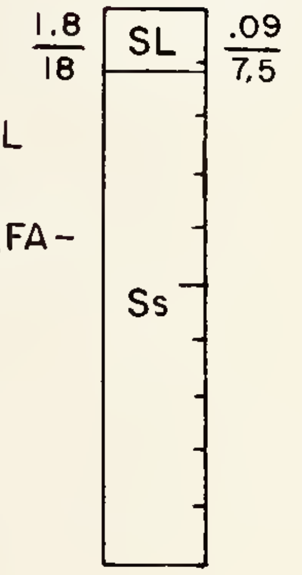


LOCATION: 1875'W, 800'S
NE COR. SEC. 28

PARENT MATERIAL: RESIDUAL SANDSTONE.

REMARKS: IRRIGATED ALFALFA-FAIR COVER. NO SAMPLES TAKEN.

NO. ㉕



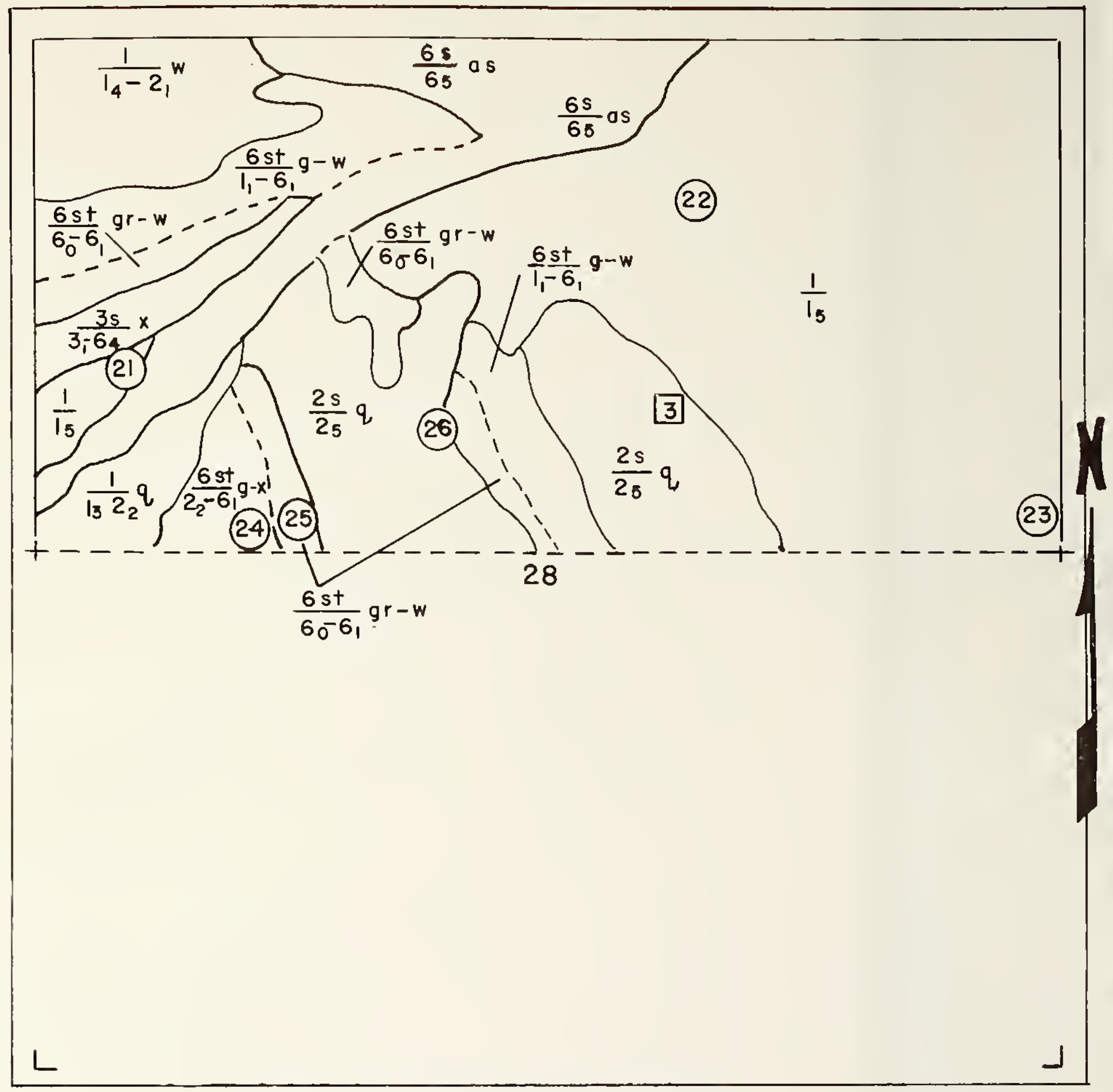
LOCATION: 1325'E, 2550'S
NW COR. SEC. 28

PARENT MATERIAL: SANDSTONE

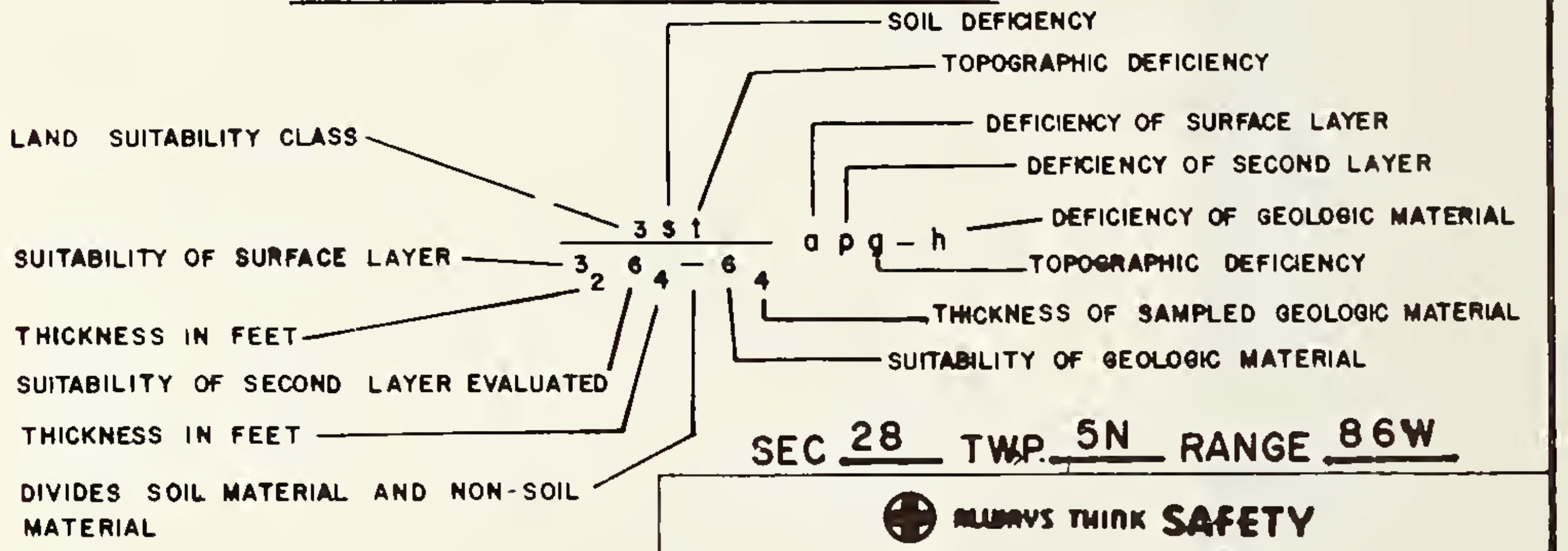
REMARKS: HARD SANDSTONE, VERY LITTLE SOIL MATERIAL, NORMALLY LESS THAN THIS PROFILE.

NO.

NO.



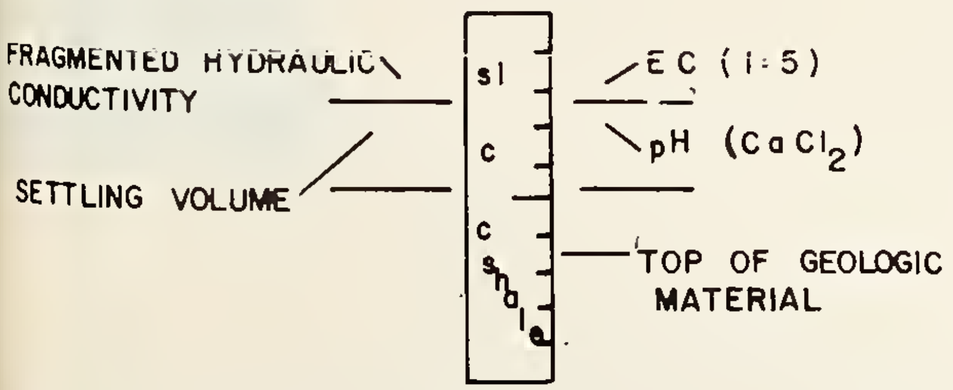
LAND SUITABILITY SYMBOLS


SOIL DEFICIENCY
TOPOGRAPHIC DEFICIENCY
LAND SUITABILITY CLASS
DEFICIENCY OF SURFACE LAYER
DEFICIENCY OF SECOND LAYER
DEFICIENCY OF GEOLOGIC MATERIAL
3 s t
a p g - h
SUITABILITY OF SURFACE LAYER
3₂ 6₄ - 6₄
TOPOGRAPHIC DEFICIENCY
THICKNESS OF SAMPLED GEOLOGIC MATERIAL
THICKNESS IN FEET
SUITABILITY OF GEOLOGIC MATERIAL
SUITABILITY OF SECOND LAYER EVALUATED
THICKNESS IN FEET
DIVIDES SOIL MATERIAL AND NON-SOIL MATERIAL

SEC 28 TWP. 5N RANGE 86W

SCALE: 1"=1000'

SOIL PROFILE KEY



SOIL PROFILE SYMBOLS

Cb	COBBLE	SiCL	SILTY CLAY LOAM
Gr	GRAVEL	SC	SANDY CLAY
S	SAND	C	CLAY
LS	LOAMY SAND	SiC	SILTY CLAY
SL	SANDY LOAM	Sh	SHALE
L	LOAM	Ss	SANDSTONE
SiL	SILT LOAM	Sis	SILTSTONE
SCL	SANDY CLAY LOAM	MUs	MUDSTONE
CL	CLAY LOAM		

INFORMATIVE APPRAISALS

OVERBURDEN DEFICIENCIES

s	SALINITY
a	SODICITY
w	WEATHERABILITY
k	SHALLOW DEPTH TO COARSE SAND, GRAVEL, OR COBBLE
b	SHALLOW DEPTH TO RELATIVELY IMPERVIOUS SUBSTRATA
v	VERY COARSE TEXTURE (SANDS, LOAMY SANDS)
h	VERY FINE TEXTURE (CLAYS)
q	AVAILABLE MOISTURE CAPACITY
i	INFILTRATION
p	PERMEABILITY
x	STONINESS

TOPOGRAPHY DEFICIENCIES

g	SLOPE
c	SURFACE ROCKS
r	BEDROCK OUTCROPS

ALWAYS THINK SAFETY

FISH CREEK STUDY SITE

LAND SUITABILITY

LANDS WERE CLASSED FOR THEIR SUITABILITY AS A SOURCE OF PLANTING MEDIA

DESIGNED ______ SUBMITTED A. SHINEMAN
DRAWN L. PETERSON RECOMMENDED ______
CHECKED T. CAPPELLUCCI APPROVED ______

LM REGION, DEN., COLO.
FIGURE C 6

LOWER MISSOURI
REGIONAL LABORATORY
SOILS AND WATER

			Hydraulic Conductivity Ins./hr.							1:5 Extract				Saturation Extract							Na Me/100g				% of Moisture	
Lab Number	Site Number	Depth Feet	6th Hr.	24th Hr.	pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	$ecx10^3$ @ 25 c	Ca+Mg Me/L	SAR Est.	Ca+Mg Me/100g	$ecx10^3$ @ 25 c	Na Me/L	Ca+Mg Me/L	SAR	Sat %	Ca+Mg Me 100g	Gyp Me 100g	Total Na	Exch. Na	Cation Exchange Capacity	ESP %		15 Bars
1	FC-1-1	0-12	.26	.20	6.4	6.0	22			.07											.06		45.0			17.0
2	2	12-36	.34	.26	6.7	6.4	23			.06											.04		48.0			17.1
3	3	36-48	.20	.10	7.1	6.7	27			.07											.04		54.0			21.8
4	4	48-60	.36	.26	7.2	7.0	27			.08											.04		52.4			18.4
5	FC-PD-1-1	0-10	.04	.00	6.5	6.1	24			.04											.02		32.6			11.8
6	2	10-31	.32	.28	7.2	6.6	25			.03											.04		37.8			16.8
7	3	31-37	.54	.54	8.1	7.3	22			.08											.06		33.0			12.2
8	4	37-51	1.4	1.4	7.2	6.8	21			.03											.04		32.4			12.7
9	5	51-57	.78	.60	8.8	7.5	23			.10											.10		31.8			15.3
10	6	57-62	9.5	3.0	9.2	7.6	22			.12				.36	2.2	2.84	1.85	45.6	.13		.44	.34	30.2	1.1		18.9
11	FC-2-1	0-8	.30	.24	7.3	6.5	23			.08											.06		35.0			18.6
12	2	8-28	.42	.32	7.5	6.5	22			.05											.04		35.0			13.8
13	3	28-36	.48	.40	8.3	6.9	22			.07											.04		35.6			26.4
14	FC-PD-2-1	0-14	.70	.82	7.2	6.0	27			.08											.02		42.4			14.0
15	2	14-19	.50	.44	7.3	6.0	27			.06											.02		37.8			17.5
16	3	19-31	.36	.30	7.1	6.0	21			.04											.02		32.4			15.7
17	4	31-38	.38	.28	7.2	6.1	22			.03											.04		31.6			16.2
18	FC-3-1	0-10	.40	.26	7.6	6.6	24			.09											.04		37.6			24.1
19	2	10-30	.68	.62	7.6	6.8	22			.06											.04		34.0			10.5
20	3	30-40	.30	.14	8.0	6.9	27			.07											.04		32.4			18.2
21	4	40-60	.22	.12	8.8	7.6	34			.10											.10		36.4			13.6
22	FC-PD-3-1	0-19	18.4	3.8	7.5	5.8	18			.04											.02		15.4			9.3
23	2	19-37	13.6	1.6	7.5	6.6	16			.04											.02		13.0			6.8
24	3	37-48	11.6	.94	7.2	6.0	18			.02											.02		22.4			6.7
25	4	48-60	4.3	1.7	7.2	6.2	19			.03											.02		14.4			5.3
26	FC-4-1	0-24	5.0	3.4	7.1	6.1	27			.09											.02		46.0			22.1
27	2	24-40	.28	.24	7.4	6.1	22			.05											.02		28.4			14.6
28	3	40-60	.52	.44	7.5	6.0	27			.04											.04		33.4			17.6
29	FC-PD-4-1	0-10	3.8	1.9	7.0	5.7	18			.03											.02		20.0			11.8
30	2	10-20	.84	.68	7.0	5.7	18			.03											.02		19.0			8.1
31	3	20-33	1.8	.09	7.2	5.9	19			.03											.02		18.0			6.9
32	4	33-62	.60	.54	7.5	6.3	20			.03											.04		21.6			4.7
33	FC-5-1	0-10	1.4	1.2	6.7	5.5	19			.04											.02		25.0			7.7
34	FC-6-1	0-6	.50	.46	8.0	7.2	27			.31				1.5	2.6	15.6	.93	61.3	.96		.20	.04	36.4	.11		13.9
35	2	6-18	1.2	1.3	8.5	7.2	24			.28				1.6	4.0	17.4	1.36	52.7	.92		.40	.19	28.0	.68		10.7
36	3	18-40	2.1	1.4	8.7	7.5	21			.24				1.5	6.3	12.2	2.55	45.2	.55		.40	.12	21.8	.55		8.8
37	4	40-60	10.2	1.3	8.6	7.4	17			.16											.10		9.8			4.5
38	FC-PD-6-1	0-6½	3.9	3.3	7.4	5.9	19			.05											.02		20.0			8.1
39	2	6½-15	6.9	1.0	7.2	5.9	18			.03											.02		18.8			7.4
40	FC-7-1	0-8	.24	.10	8.1	7.2	29			.07											.04		42.0			19.7
41	2	8-18	.20	.18	8.6	7.5	29			.11											.08		40.0			18.0
42	3	18-24	.34	.20	8.7	7.5	31			.14				.37	.48	4.40	.32	55.5	.24		.10	.07	42.4	.17		19.9
43	4	24-36	.20	.20	9.1	7.7	29			.14											.20		35.0			23.9
44	5	36-48	.32	.30	9.3	7.8	31			.16				.50	3.0	3.00	2.45	52.1	.16		.42	.27	31.8	.85		12.2
45	6	48-60	.24	.24	9.0	7.8	29			.20											.52		30.4			19.5
46	FC-PD-7-1	0-20	.08	.04	7.7	6.9	31			.21				.97	2.7	9.00	1.27	60.4	.54		.20	.04	47.0	.09		16.9
47	2	20-26	.26	.20	8.3	7.5	29			.35						Insufficient Sample										15.0
48	3	26-32	.12	.10	8.3	7.7	30			.35				2.0	6.6	20.4	2.07	55.3	1.1		.48	.12	39.0	.31		12.2
49	4	32-54	.80	.74	8.3	7.7	26			.33				1.8	6.0	16.5	2.09	49.5	.82		.42	.13	38.0	.34		10.6
50	5	54-60	.68	.90	8.5	7.6	31			.25				1.3	5.0	11.4	2.09	46.4	.53		.76	.53	26.0	2.0		15.0
51	FC-9-1	0-12	-	-	8.3	6.8	28			.18				1.5	.13	4.24	8.97	52.3	.22		8.2	1.3	32.4	4.0		13.2
52	2	12-36	.20	.32	8.1	8.0	33			2.9				11.1	.98	102	13.7	59.1	6.0		12.2	6.4	33.6	19.0		16.0
53	3	36-60	.08	.09	8.4	8.1	36			3.0				13.8	135	110	18.2	58.5	6.4		11.0	3.1	33.8	9.2		20.0
54	FC-10-1	0-8	.38	.20	7.5	7.4	31			.19											.38		45.0			19.5
55	2	8-36	-	.03	8.8	7.7	41			.19											1.4		47.0			21.1
56	3	36-44	.34	.38	7.9	7.6	31			1.5				3.6	12	45.8	2.51	59.3	2.7		1.4	.64	37.0	1.7		23.3
57	FC-12-1	0-4	.92	1.2	6.9	6.3	30			.16											.70		57.0			19.4
58	2	4-14	.04	-	7.1	6.4	29			.38				6.8	62	40.0	13.9	60.1	2.4				50.4			18.0
59	3	14-30	.08	.03	8.2	7.8	36			1.4				2.2	13	17.4	4.41	65.1	1.1		7.6	6.8	39.6	17.1		16.6
60	4	30-60	-	-	8.8	7.8	47			.75				4.2	34	22.0	10.3	59.3	1.3		4.4	2.4	28.0	8.6		16.7
61	FC-13-1	0-10	1.1	1.4	7.6	6.5	30			.10											.30		47.0			20.0
62	2	10-44	-	-	8.1	7.3	39			.27				1.1	3.0	9.80	1.36	68.1	.67		.80	.60	49.0	1.2		18.3
63	3	44-60	.08	.05	7.8	7.7	39			1.3				3.6	12	46.8	2.48	61.4	2.9		2.4	1.7	42.0	4.0		15.1

LM-813 (Rev. 12/76)
Interior-Reclamation
Lower Missouri Region

LOWER MISSOURI
REGIONAL LABORATORY
SOILS AND WATER

			Hydraulic Conductivity Ins./hr.							1:5 Extract				Saturation Extract							Na Me/100g				% of Moisture	
Lab Number	Site Number	Depth Feet	6th Hr.	24th Hr.	pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	ecx10^3 @ 25 c	Ca+Mg Me/L	SAR Est.	Ca+Mg Me/100g	ecx10^3 @ 25 c	Na Me/L	Ca+Mg Me/L	SAR	Sat %	Ca+Mg Me 100g	Gyp Me 100g	Total Na	Exch. Na	Cation Exchange Capacity	ESP %		15 Bars
64	FC-15-1	0-10	2.8	1.4	6.8	6.0	23			.09											.16		19.8			7.5
65	2	10-40	2.1	1.3	6.8	5.9	21			.04											.16		15.6			4.7
66	3	40-60	5.3	.81	7.1	6.3	17			.04											.16		13.2			9.9
67	FC-16-1	0-12	.60	.70	7.1	6.2	23			.09											.20		47.0			11.8
68	2	12-36	.42	.46	7.2	6.5	21			.07											.24		41.8			7.3
69	3	36-60	.34	.31	8.1	7.2	21			.12											1.1		30.0			20.4
70	FC-24-1	0-6	2.0	2.3	8.3	7.4	26			.10											.20		34.0			16.8
71	2	6-20	.48	.59	8.6	7.3	26			.10											.24		30.2			12.6
72	3	20-25	.16	.13	8.7	7.3	28			.09											.24					3.0
73	FC-25-1	0-6	1.1	1.8	8.6	7.5	18			.09											.24		10.4			2.7
74	FC-26-1	0-12	3.1	2.3	6.4	5.2	19			.06											.16		12.4			4.7
75	2	12-54	6.0	2.6	6.1	5.4	19			.05											.16		11.4			3.2
76	3	54-60	5.4	2.8	6.6	5.8	17			.03											.16					10.6
77	FC-27-1	0-8	.46	.51	6.1	5.1	19			.03											.20		30.0			11.2
78	2	8-28	.46	.36	6.2	5.1	23			.03				1.9	.25	2.04	.25	38.1	.08		.22	.21	30.4	.69		8.9
79	3	28-40	.54	.36	6.3	5.2	22			.03											.16		25.0			17.7
80	4	40-48	.18	.13	6.4	5.3	30			.03											.30		39.0			18.6
81	5	48-60	2.2	.98	6.4	5.3	19			.03											.22		34.0			17.4
82	FC-28-1	0-9	.48	.64	6.3	5.3	19			.04											.16		19.2			13.4
83	2	9-26	.42	.35	6.9	6.3	22			.04											.18		27.6			13.9
84	3	26-38	.28	.14	7.2	6.6	23			.04											.20		24.4			8.9
85	4	38-60	.60	.48	8.6	7.8	21			.10											.32		19.2			13.9
86	FC-29-1	0-12	.18	.12	8.3	7.2	25			.19											.82		37.6			14.3
87	2	12-30	.16	.09	8.9	7.8	21			.35				2.5	.18	13.0	7.06	47.3	.61		2.2	1.3	29.0	4.6		10.9
88	3	30-42	.18	.09	9.0	7.8	24			.35				2.2	.16	10.2	7.08	53.4	.54		2.6	1.7	24.8	7.0		15.0
89	4	42-50	.30	.16	8.9	7.8	25			.31				1.7	.12	9.28	5.56	52.4	.49		1.8	1.2	33.6	3.6		16.2
90	5	50-58	.24	.22	8.7	7.8	28			.28											1.3		27.4			9.4
91	FC-30-1	0-14	.14	.07	8.4	7.4	25			.28											1.4		39.0			16.5
92	2	14-30	.44	.42	8.9	7.8	22			.21				1.1	5.7	7.36	2.96	44.9	.33		.90	.65	27.0	2.4		9.1
93	3	30-42	.14	.12	8.9	7.8	22			.33				2.0	.12	14.2	4.50	48.5	.69		1.4	.83	26.4	3.1		10.8
94	4	42-60	.12	.08	8.5	7.7	25			.21											.60		24.0			10.2
95	FC-31-1	0-10	.58	.55	7.1	6.0	22			.07											.22		25.8			8.8
96	2	10-18	.36	.25	7.0	5.9	22			.03											.20		28.4			10.8
97	3	18-33	.78	.75	7.2	6.2	22			.03											.24		31.8			11.7
98	4	33-38	.54	.74	7.6	6.8	22			.04											.22		31.8			10.7
99	5	38-44	.44	.39	8.6	7.5	22			.08											.26		27.8			10.1
100	FC-35-1	0-10	.08	-	7.4	6.8	26			1.1				7.1	.38	77.0	6.13	55.0	4.2		3.4	1.3	35.8	3.6		15.4
101	2	10-24	.22	.20	8.0	7.8	37			2.5				10.9	.83	110	11.2	62.7	6.9		8.4	3.2	41.6	7.7		13.7
102	3	24-36	-	.07	8.2	8.0	33			2.5				9.5	.73	89.4	10.9	59.3	5.3		6.0	1.7	36.0	4.7		17.2
103	4	36-60	-	.04	8.7	8.0	36			.85				4.4	.30	32.0	7.5	61.8	2.0		3.4	1.5	34.4	4.4		12.1
104	FC-37-1	0-10	4.8	2.5	6.9	6.4	24			.15											.18		23.6			10.8
105	2	10-24	2.3	.62	6.9	6.1	20			.04											.16		19.0			8.8
106	3	24-40	2.7	1.1	6.9	5.9	18			.04											.16		17.0			9.4
107	4	40-52	1.4	1.2	6.8	5.9	17			.03											.16		14.4			7.0
108	DH #4 5	52-60	1.2	.84	6.9	6.0	19			.03											.20		20.4			9.3
109	~~FC-41-1~~	0-6	4.2	1.1	6.8	6.3	25			.10											.32		38.4			16.7
110	2	6-20	.44	.24	6.9	6.0	25			.05											.30		37.0			15.5
111	3	20-38	.22	.20	6.9	5.9	23			.05											.60		37.8			14.4
112	4	38-50	.20	.06	8.0	6.8	25			.07											1.2		33.6			17.7
113	5	50-60	.14	.04	8.7	7.3	26			.09											1.6		33.8			18.4
114	FC-42-1	0-10	.34	.14	6.4	5.4	21			.05											.24		21.0			9.2
115	2	10-24	.18	.06	7.7	6.6	30			.05											1.0		47.8			18.2
116	3	24-45	.16	.04	9.0	7.6	31			.20											2.0		42.4			17.5
117	4	45-53	.60	.44	7.9	7.7	30			1.9				4.9	.25	52.0	4.9	59.9	3.1		8.8	7.3	48.4	15.1		19.4
118	DH-1-1	0-9	1.4	.96	6.2	5.8	19			.06											.20		20.8			7.2
119	2	9-16	1.2	1.2	6.4	5.8	19			.04											.20		18.4			7.1
120	3	16-20	2.0	2.0	6.1	6.0	18			.03											.20		16.0			6.9
121	4	20-24	1.4	.88	6.5	6.4	19			.03											.20		15.4			6.7
122	5	24-28	1.7	1.4	6.3	6.2	19			.03											.20		17.8			4.0

LOWER MISSOURI
REGIONAL LABORATORY
SOILS AND WATER

			Hydraulic Conductivity Ins./hr.							1:5 Extract				Saturation Extract							Na Me/100g				% of Moisture	
Lab Number	Site Number	Depth Feet	6th Hr.	24th Hr.	pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	ecx10^3 @ 25 c	Ca+Mg Me/L	SAR Est.	Ca+Mg Me/100g	ecx10^3 @ 25 c	Na Me/L	Ca+Mg Me/L	SAR	Sat %	Ca+Mg Me 100g	Gyp Me 100g	Total Na	Exch. Na	Cation Exchange Capacity	ESP %		15 Bars
123	OH-1-1	0-7.5	.76	.48	7.4	7.3	25			.39				3.9	7.5	56.3	1.4	62.8	3.5		.80	.33	43.0	.77		16.0
124	2	7.5-12.8	.18	.18	7.6	7.3	29			.46				2.4	4.8	29.2	1.3	61.9	1.8		.64	.34	40.6	.84		16.6
125	3	12.8-13.6	.66	.70	8.1	8.0	23			.40							Ins. Sample				.70		30.0			12.1
126	4	13.6-18.7	.60	.50	8.0	7.9	19			.37				3.4	8.0	42.5	1.7	34.3	1.5		.46	.19	13.0	1.5		6.6
127	5	18.7-25	.58	.22	8.4	8.0	20			.33				3.0	22.7	15.1	8.3	27.4	.41		1.2	.58	11.4	5.1		6.4
128	6	25-30	.88	.26	7.7	7.6	20			.28											1.2		13.0			6.3
129	OH-2-1	0-24	.16	.04	7.6	7.3	24			.16											.64		37.0			15.9
130	2	24-33	.14	.18	7.1	7.0	29			1.1				5.0	26.9	52.7	5.2	61.6	3.2		3.0	1.34	38.4	3.5		16.3
131	3	33-39	.30	.16	8.2	8.1	28			1.8				6.6	33.8	73.2	5.6	60.5	4.4		4.0	1.96	38.2	5.1		16.1
132	4	39-52	.22	.46	7.7	7.6	27			2.7				6.7	29.9	81.5	4.7	57.5	4.7		3.4	1.68	31.8	5.3		16.8
133	OH-3-1	0-5	.58	.64	7.9	7.8	24			1.5				4.9	17.2	63.0	3.1	56.7	3.6		1.8	.82	34.4	2.4		16.9
134	2	5-14	.70	1.3	8.4	7.9	29			.37				2.4	10.2	22.1	3.1	53.2	1.2		1.2	.66	34.4	1.9		15.2
135	3	14-20	.38	-	8.7	8.1	22			.26											2.6		31.0			12.0
136	4	20-24.5	-	-	9.0	8.2	25			.38				1.8	17.0	2.62	14.9	44.2	.12		6.4	5.66	34.0	16.6		14.5
137	5	24.5-31.5	-	-	9.3	8.3	28			.53				3.2	34.4	1.80	36.3	50.2	.09		11.0	9.27	31.0	29.9		15.4
138	6	31.5-38.5	-	-	9.6	8.4	30			.57				2.6	29.1	1.08	39.6	56.0	.06		15.8	14.2	30.4	46.6		15.5
139	7	38.5-45.5	-	-	9.6	8.5	29			.61				2.7	31.8	0.96	45.9	56.4	.05		17.2	15.4		53.5		22.0
140	8	45.5-52.5	-	-	9.6	8.5	30			.57				2.5	28.2	1.16	37.0	60.5	.07		17.2	15.5	29.4	52.7		20.9
141	9	52.5-57.5	-	-	9.7	8.8	34			.61				2.5	26.2	1.08	35.7	60.7	.07		19.0	17.4	30.0	58.0		23.3
142	10	57.5-63.0	-	-	10.0	8.9	43			.77				2.3	26.0	1.00	36.8	75.1	.08		20.4	18.5		54.9		31.8
143	11	63.0-69.3	-	-	9.8	8.7	35			.71				2.8	32.0	1.52	36.7	55.8	.09		19.0	17.2	39.6	43.5		23.0
144	12	69.3-76.8	-	-	9.4	8.2	29			.46				3.3	38.0	1.60	40.2	28.6	.05		6.0	4.97		67.2		6.9
145	13	76.8-84.0	-	-	9.6	8.2	26			.57				2.8	31.0	1.28	38.8	45.2	.06		10.0	8.60	25.6	33.6		17.1
146	14	84.0-99.3	-	-	9.9	8.2	18			.14				.62	6.5	0.52	12.7	42.2	.02		4.2	3.90		109		0.28
147	15	99.3-107	-	-	10.3	8.5	18			.14											1.8					4.4
148	16	107-115	-	-	10.1	8.4	18			.23				.74	6.2	.52	12.2	44.5	.02		2.0	1.72		50.6		4.7
149	PO-5-1	0-8	.50	.68	8.5	7.7	23			.10											1.3		41.0			20.1
150	2	8-24	-	-	9.4	8.0	24			.13											.48		41.0			20.6
151	3	24-32	-	-	9.3	8.0	27			.16											.84		44.2			21.1
152	4	32-40	.06	.04	9.0	8.0	26			.19											1.0		44.6			21.3
153	5	40-48	.04	-	8.2	8.0	26			.48				2.2	7.5	22.7	2.23	61.2	1.39		1.1	0.64	41.0	1.6		21.0
154	OH-4-1	0-3	.06	.98	8.6	7.3	23			.153											1.6		38.0			18.5
155	2	3-5.5	-	-	8.3	7.7	23			.913				4.1	27.0	35.2	6.4	54.9	1.9		3.2	1.8	32.0	5.5		17.2
156	3	5.5-10	.18	.42	8.5	8.0	25			.757				4.0	24.8	38.1	5.7	59.3	2.3		3.2	1.7	34.6	5.0		16.3
157	4	10-17.5	.12	.08	9.3	8.0	23			.505				2.8	19.1	20.4	6.0	49.6	1.0		2.0	1.1	28.8	3.6		13.8
158	5	17.5-21.5	1.46	2.20	8.5	7.7	24			.517				2.7	19.1	16.6	6.6	45.3	.75		2.2	1.3	21.8	6.1		11.7
159	6	21.5-28.5	.72	1.20	9.0	8.0	23			.542				3.7	28.0	21.6	8.5	39.7	.86		2.6	1.5	20.0	7.5		10.5
160	7	28.5-35.5	.06	-	9.2	8.1	24			.409				3.2	26.2	13.4	10.1	37.5	.50		2.8	1.9	18.0	10.3		9.5
161	8	35.5-42.5	-	-	9.4	8.2	20			.337				2.4	24.0	3.23	18.9	30.7	.10		2.3	1.6	16.4	9.5		8.0
162	9	42.5-51.5	-	-	9.7	8.4	25			.480				2.4	28.2	0.89	42.3	40.2	.04		6.2	5.1	18.0	28.2		10.4
163	10	51.5-56.3	-	-	9.8	8.5	35			.607				2.6	29.5	1.00	41.7	58.1	.06		14.0	12.3	26.0	47.3		17.1
164	11	56.3-58.3	-	-	10.1	8.5	27			.576				2.3	26.5	0.50	53.0	49.0	.02		12.2	10.9	22.4	48.7		12.3
165	12	58.3-64.1	-	-	10.0	8.5	28			.662				2.5	26.5	0.90	39.5	55.9	.05		13.4	11.9	26.6	44.8		18.5
166	13	64.1-65.5	-	-	9.7	8.6	28			.631				2.4	27.2	1.35	33.1	58.1	.08		15.4	13.8	26.0	53.2		19.0
167	14	65.5-72	-	-	10.1	8.6	33			.628				3.0	36.2	1.10	48.8	73.4	.08		19.0	16.3	30.0	54.5		21.7
168	15	72-80	-	-	9.8	8.6	33			.717				3.4	39.6	1.05	54.6	71.0	.07		18.0	15.2	32.2	47.2		25.8
169	16	80-90.3	-	-	9.9	8.6	30			.629				3.3	38.4	0.85	58.9	67.2	.06		17.0	14.4	27.0	53.4		19.6
170	17	90.3-98	-	-	10.3	8.5	36			.732				3.4	39.0	1.35	47.5	66.7	.09		15.4	12.8	29.6	43.2		19.1
171	18	98-107.8	-	-	9.8	8.6	36			.556				2.9	35.0	0.75	57.2	69.4	.05		16.0	13.6	31.0	43.8		21.2
172	19	107.8-115	-	-	9.9	8.5	30			.589				2.7	32.2	0.95	46.7	70.5	.07		16.4	14.1	30.4	46.5		19.6
173	20	115-125.3	-	-	10.0	8.5	25			.622				1.9	33.0	0.60	60.3	63.6	.04		17.0	14.9	29.0	51.4		17.6
174	21	125.3-131	-	-	9.9	8.5	27			.746				3.6	43.8	1.00	61.9	61.4	.06		17.0	14.3	23.6	60.6		18.3
175	22	131-137	-	-	9.9	8.6	25			.589				2.9	34.4	0.50	68.8	64.3	.03		17.0	14.8	30.0	49.3		19.2
176	23	137-142.9	-	-	9.8	8.4	24			.658				3.0	35.0	1.00	49.5	60.1	.06		14.8	12.7	25.0	50.8		16.4
177	24	142.9-150	-	-	10.0	8.4	23			.674				3.5	43.0	1.25	54.4	53.7	.07		14.2	11.9	23.6	50.3		14.3
178	25	150-160.3	-	-	9.4	8.3	33			.635				2.5	32.0	0.85	49.1	65.2	.06		18.0	15.9	32.0	49.7		17.8
179	26	160.3-168	-	-	9.7	8.5	33			.674				3.1	38.0	0.75	62.1	58.1	.04		19.0	16.8	31.8	52.8		23.1
180	27	168-172.9	-	-	9.8	8.4	31			.500				2.4	31.0	1.00	43.8	56.0	.06		14.8	13.1	27.6	47.3		16.7
181	28	177.9-182.6	-	-	9.8	8.5	31			.505				2.5	29.9	1.55	34.0	57.3	.09		16.0	14.3	29.0	49.3		15.4
182	29	182.6-187.5	-	-	10.3	8.8	35			.601				2.4	29.1	0.70	49.2	70.3	.05		20.0	18.0	35.0	51.3		22.0
183	30	187.5-192.2	-	-	10.0	8.5	27			.570				2.8	28.0	.43	60.4	54.2	.02		17.0	15.5	29.0	53.4		23.0
184	31	192.2-194.8	-	-	10.0	8.6	30			.570				3.2	32.0	.74	52.6	49.6	.04		16.0	14.4	29.0	49.7		18.6
185	32	194.8-196.3	-	-	10.3	8.4	21			.365				2.3	24.0	.40	53.7	43.8	.02		7.2	6.1	14.4	42.7		11.6
186	33	200.1-204.4	-	-	9.6	8.3	20			.293				1.7	17.2	.84	26.5	42.3	.04		8.6	7.9	19.0	41.4		14.9
187	34	204.5-210.3	-	-	9.8	8.1	26			.153				.73	7.4	.30	19.1	51.3	.02		3.8	3.4	6.8	50.3		10.2

LOWER MISSOURI
REGIONAL LABORATORY
SOILS AND WATER

Lab Number	Site Number	Depth Feet	Hydraulic Conductivity Ins./hr.		pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract				Saturation Extract						Gyp Me 100g	Na Me/100g		Cation Exchange Capacity	ESP %	% of Moisture	
			6th Hr.	24th Hr.						ecx10^3 @ 25 c	Ca+Mg Me/L	SAR Est.	Ca+Mg Me/100g	ecx10^3 @ 25 c	Na Me/L	Ca+Mg Me/L	SAR	Sat %	Ca+Mg Me 100g		Total Na	Exch. Na				15 Bars
188	OH-5-1	0-2"	.18	.12	7.4	6.4	22			.100											.24		36.0			13.0
189	2	2-18"	.24	.14	8.5	7.6	22			.127											.22		37.8			20.0
190	3	18-24"	.38	1.6	9.0	8.0	23			.118											.34		37.8			18.9
191	4	24-28"	.38	.64	9.0	8.0	24			.108											.30		38.0			19.2
192	5	28-45"	-	-	9.3	8.3	28			.818				5.3	29.2	46.2	6.1	54.3	2.5		3.6	2.0	34.4	5.9		16.3
193	6	45-56"	.06	.06	9.1	8.2	26			.122											.54		23.0			16.7
194	OH-5-1	0-5	.84	2.3	8.5	8.0	22			.473				3.8	13.0	43.7	2.8	56.3	2.5		1.30	.57	35.8	1.6		17.8
195	2	5-9.5	.32	.62	8.0	7.0	26			1.68				6.2	27.5	68.5	4.7	55.9	3.8		2.42	.88	30.0	2.9		20.1
196	3	9.5-17.2	.26	.26	9.3	8.0	22			.505				5.4	31.0	46.4	6.4	42.1	2.0		2.60	1.29	28.0	4.6		14.4
197	4	17.2-25.1	-	-	9.6	8.2	22			.509				3.9	34.4	6.4	19.2	38.5	.25		3.90	2.58	23.8	10.8		10.8
198	5	25.1-31	-	-	9.6	8.1	24			.777				4.2	46.4	1.4	75.9	53.7	.08		13.2	9.74	28.4	34.3		15.6
199	6	31-38.3	-	-	9.8	8.3	27			.848				3.6	40.0	.78	64.0	66.7	.05		17.0	14.3	31.0	46.2		23.3
200	7	38.3-38.7	Ins.	Sample	10.2	8.3	18			.487					Ins.	Sample					8.00		18.8			5.5
201	8	38.7-44	-	-	10.4	8.9	58			.965				1.9	22.4	.42	48.9	116.7	.05		22.4	19.8	41.0	48.3		32.0
202	9	44-48	-	-	10.0	8.3	26			.670				2.8	32.4	.46	67.6	62.6	.03		11.0	8.97	26.0	34.5		28.8
203	10	48-52.7	-	-	10.0	8.3	25			.614				2.5	29.0	.54	55.8	57.7	.03		12.8	11.1	23.0	48.4		18.0
204	11	52.7-56.7	-	-	10.3	8.3	24			.553				2.5	29.9	.40	66.9	53.0	.02		10.4	8.8	19.4	45.4		18.5
205	12	56.7-60.2	-	-	10.1	8.3	23			.713				2.9	32.4	.66	56.4	55.2	.04		12.8	11.0	28.4	38.8		18.3
206	13	60.2-67	-	-	10.0	8.1	22			.725				4.7	52.0	1.20	67.1	55.2	.07		14.8	11.9	28.8	41.4		16.0
207	14	67-72	-	-	10.0	8.3	26			.751				2.7	31.0	.44	66.1	65.6	.03		14.4	12.4	28.8	42.9		21.4
208	15	72-77.2	-	-	10.3	8.3	28			.654				2.5	29.5	.48	60.2	63.3	.03		15.8	13.9	28.4	49.1		20.1
209	16	77.2-81.9	-	-	10.3	8.3	27			.645				2.4	26.9	.54	51.8	67.1	.04		15.2	13.4	26.0	51.5		19.7
210	17	81.9-85.9	-	-	10.1	8.3	27			.632				2.5	27.9	.46	58.2	65.5	.03		12.8	11.0	27.8	39.5		23.6
211	18	85.9-90.9	-	-	10.0	8.3	27			.585				2.5	28.5	.44	60.8	66.2	.03		14.4	12.5	27.8	45.0		26.3
212	19	90.9-95.1	-	-	10.3	8.3	30			.654				2.6	29.0	.48	59.2	67.0	.03		17.0	15.1	30.0	50.2		25.5
213	20	95.1-99.1	-	-	10.1	8.4	28			.674				2.9	31.8	.50	63.6	66.9	.03		15.2	13.1	28.0	46.7		28.6
214	21	99.1-104	-	-	10.5	8.4	30			.618				2.5	27.5	.17	94.3	71.2	.01		18.4	16.4	28.4	57.9		27.5
215	22	104-108	-	-	10.2	8.4	45			.556				2.1	23.1	.50	46.2	84.4	.04		20.4	18.5	33.4	55.2		31.0
216	23	108-111.5	-	-	10.3	8.3	25			.618				2.6	28.5	.68	48.9	62.0	.04		15.0	13.2	23.6	56.1		20.1
217	24	111.5-115	-	-	10.5	8.3	26			.695				2.9	32.0	.68	54.9	56.7	.04		13.4	11.6	22.4	51.7		18.1
218	25	115-120	-	-	10.2	8.4	29			.618				2.8	31.6	.52	62.0	57.4	.03		15.0	13.2	23.0	57.3		21.9
219	26	120-124.5	-	-	10.1	8.4	29			.570				2.6	29.0	.44	61.8	54.9	.02		15.4	13.7	26.8	51.0		20.5
220	27	124.5-129	-	-	9.8	8.4	26			.585				2.6	29.5	.56	55.8	56.0	.03		14.8	13.1	22.4	58.7		20.9
221	28	129-135	-	-	9.9	8.1	30			.681				2.7	29.5	.56	55.8	54.5	.03		14.0	12.4	22.4	55.3		18.9
222	29	135-140	-	-	9.7	8.2	32			.690				2.5	28.5	.54	54.9	57.5	.03		14.4	12.8	23.0	55.5		22.9
223	30	140-145	-	-	9.8	8.4	34			.569				2.5	29.0	.50	58.0	58.4	.03		15.0	13.3	21.6	61.6		20.8
224	31	145-150	Ins.	Sample	9.8	8.6	36			.591				2.4	27.5	.56	52.0	66.5	.04		16.4	14.6	27.2	53.7		22.8
225	32	150-154	-	-	9.7	8.3	32			.750				3.8	42.0	.72	70.0	62.4	.04		15.4	12.8	29.8	42.9		22.8
226	33	154-159	-	-	9.7	8.0	39			.709				3.8	40.4	.94	58.9	55.3	.05		14.4	12.2	23.8	51.1		18.0
227	34	159-163.9	-	-	9.9	8.5	33			.714				2.9	33.0	.64	58.3	62.1	.04		14.6	12.6	24.0	52.3		23.4
228	35	163.9-168	-	-	9.7	8.3	34			.729				2.9	32.0	.70	54.1	63.2	.04		15.2	13.2	24.2	54.5		19.3
229	36	168-173	-	-	9.6	8.5	30			.575				2.2	24.5	.54	47.2	59.9	.03		14.4	12.9	20.4	63.2		14.1
230	37	173-179.5	-	-	9.8	8.2	34			.591											13.2		21.8			16.8
231	38	179.5-185	-	-	9.7	8.0	29			.609											10.0		17.8			11.9
232	39	185-190	-	-	10.0	8.2	35			.635											14.4		24.0			17.3
233	40	190-197.5	-	-	9.9	8.5	37			.508											14.2		24.0			19.4
234	OH-3-1	0-10"	-	-	6.8	5.4	21			.069																5.9
235	2	10-24"	-	-	6.9	5.6	19			.035																4.5
236	3	24-38"	2.1	1.0	6.6	5.3	22			.044																11.9
237	4	38-48"	.86	.94	6.5	5.6	21			.030																10.6
238	5	48-60"	.68	1.6	7.2	6.4	18			.032																7.2
239	OH-3-1	0-7	2.6	1.9	7.3	6.5	18			.063																7.5
240	2	7-12	3.7	.62	8.4	7.4	17			.873																4.0
241	3	12-18	3.7	.56	7.1	6.6	16			.164																3.2
242	4	18-24.8	.30	.36	7.8	7.2	19			.209																9.0
243	5	24.8-28.2	-	-	8.1	7.1	15			.092																3.5
244	6	28.2-33	-	-	8.3	7.3	17			.114																3.8
245	7	33-37	-	-	8.2	7.0	16			.095																3.2
246	8	37-42.9	-	-	8.1	7.7	18			.125																3.0
247	9	42.9-47	-	-	8.8	7.9	18			.133																4.4
248	10	47-52.5	-	-	9.1	7.8	18			.150																3.8
249	11	52.5-57	-	-	8.9	7.7	19			.177																4.8
250	13	57.1-62	-	-	9.0	7.8	18			.140																2.6

LM-813 (Rev. 12/76)
Interior-Reclamation
Lower Missouri Region

LOWER MISSOURI
REGIONAL LABORATORY
SOILS AND WATER

GPO 838-360/29

Lab Number	Site Number	Depth Feet	Hydraulic Conductivity Ins./hr.		pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract				Saturation Extract						Gyp Me 100g	Na Me/100g		Cation Exchange Capacity	ESP %	% of Moisture	
			6th Hr.	24th Hr.						$ecx10^3$ @ 25 c	Ca+Mg Me/L	SAR Est.	Ca+Mg Me/100g	$ecx10^3$ @ 25 c	Na Me/L	Ca+Mg Me/L	SAR	Sat %	Ca+Mg Me 100g		Total Na	Exch. Na				15 Bars
251	DH-3-14	62-69	-	-	9.1	7.5	20			.212																4.1
252	16	69.1-72.5	-	-	9.5	8.0	19			.212																4.2
253	17	72.5-82	-	-	9.4	7.9	19			.303																7.5
254	18	82-92	-	-	9.6	8.3	25			.393																18.2
255	19	92-97	-	-	9.8	8.2	22			.353																10.8
256	20	97-106	-	-	9.6	8.3	24			.424																12.5
257	21	106-112.7	-	-	9.8	8.4	25			.393																10.9
258	22	112.7-123	-	-	9.8	8.4	25			.372																14.3
259	23	123-129	-	-	9.7	8.5	25			.400																12.7
260	24	129-135	-	-	9.7	8.4	20			.312																10.0
261	25	135-140	-	-	9.7	8.1	26			.442																11.8
262	26	140-151.5	-	-	9.6	8.6	19			.321																6.5
263	27	151.5-154	-	-	9.6	8.9	22			.366																7.8
264	28	154-160.8	-	-	9.4	9.2	27			.230																3.0

Please note laboratory numbers OH-5-1 and DH-3-1; these profiles are in inches rather then feet.

SCREENABLE SOIL CHARACTERIZATION
AS RELATED TO
LAND RECLAMATION

By

William B. Peters, Luvern L. Resler, and Robert Vader [1]

Soil is characterized by laboratory methods to confirm judgment in field appraisals. There is a tendency among most laboratory activities to "over test"; i.e., perform too many or unnecessary tests on certain soils at the expense of not performing essential or critical testing on particular samples. Also, laboratory activities tend to emphasize comprehensive analyses of samples from master sites and neglect selection, sequence, and quality control in mass testing performed on a screenable basis. The latter-type testing is frequently handled as routine work utilizing the least dependable personnel and considered not worthy of competent and close supervision. Thus, too often the screenable laboratory testing becomes a liability rather than an asset in supporting land classification surveys. Because the screenable testing represents coverage of areas involving a high sampling density, it serves as an extremely important input into land categorization. Therefore, it should be administered for performance with respect to both quality and quantity commensurate with the goals and objectives of the investigation.

The objective of characterizing soil and overburden will be to support judgment in estimating land reclamation potential. (Overburden refers to the material consolidated or unconsolidated overlying minable resources in relation to surface mining.) Thus, the laboratory analyses must be performed on an action program basis and serve a practical purpose. Therefore, it is essential the physical and chemical characteristics of the soil and overburden be appraised in relation to edaphology; i.e., a medium suitable for the support of plant growth, rather than pedology.

Because the laboratory studies should serve to support field appraisals, all laboratory work should be closely coordinated with fieldwork. For full effectiveness, laboratory studies must be preceded by field studies. The number and type of studies will be determined by area conditions - particularly variability, the controlling project specifications, and needs. There should be a joint plan between field and laboratory investigations prior to taking of samples if maximum utilization of data is to be obtained. Problems should be studied rather than standard or routine tests made [Kellogg, 1962].

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In submitting soil samples for laboratory characterizations, the laboratory should be furnished with pertinent field appraisals along with the tentative land utilization and quality designation. The soil and subsoil samples should represent genetic horizons with no more than 60-cm depth per sample. Substrata samples should represent uniform overburden with no more than 200 cm per sample unless drill hole diameters preclude obtaining sufficient material for laboratory and greenhouse studies.

The first priority in laboratory characterization should be accomplished by direct and indirect measurements for evaluating soil structure and its stability, soil-cation-exchange capacity or surface area, and soil reaction. After this is accomplished, then consideration should be given to testing that confirms, explains the causes of phenomena previously observed or predicted, reveals the presence of toxic elements (salinity level, boron content, alkali, acidity, reduction products, etc.), and indicates what and how much is required to cope with the soil deficiency under eventual field conditions and the moisture regimen expected to prevail [Peters, 1965].

Based on present knowledge of the area, the support characterizations should include field measurements for water movement and retention in soil and laboratory determinations for structure stability [Gardner, 1945] through measurements of floc volume and hydraulic conductivity of fragmented samples; moisture retentivity at 15-bars pressure; soil reaction by measurement of pH in water and neutral salt solution; soil salinity by measurement of specific electrical conductance of soil-water extracts; soil solution concentration and composition including sodium and calcium plus magnesium; cation exchange capacity; exchangeable cation status; residual gypsum; gypsum requirement; acid soluble carbonates; and others.

Samples collected in a reduced state may be alkaline or neutral while reduced, but acid when oxidized. Therefore, we should be on the "lookout" for such conditions and characteristics and assure reduced material is also analyzed in an aerated condition. Samples exhibiting acidity upon oxidation should be further analyzed to ascertain reduction products associated with the observed phenomenon.

Should conventional acidity; i.e., other than oxidation product, be encountered, the testing will be expanded to include acidity by measurement of neutral salt exchange acidity including aluminum, titratable acidity (amount of acidity neutralized at a selected pH), and soluble aluminum.

In screenable testing, the characterization for moisture retentivity at pressures less than 15 bars is not recommended unless a suitable use can be established. Measurements of moisture retentivity at 15-bars pressure are recommended because water content at this potential is usually correlated with several characteristics including amount and kind of clay, surface area, and cation exchange capacity. Moisture percentages at this potential would probably not be applicable in simulating water content at wilting for native vegetation.

In initial screening, diluted soil-water suspensions may be substituted for the time-consuming, saturated soil extracts in measuring electrical conductance provided limitations are ascertained. The reliability of higher moisture contents even as a tool in screening depends on the kind of salts present. For chloride salts, the results will be only slightly affected by the moisture content, but if sulfate or carbonate salts, which have relatively low solubility, are present in appreciable quantities, the apparent amount of soluble salt will depend on the soil-water ratio [Richards, 1954].

We do not concur in the practice of characterizing vast numbers of samples for textural class through measurements of particle-size distribution. This blanket laboratory analysis for soil textural class is neither required nor desired. Particle-size analysis should be limited to master site characterization, the occasional confirmation of field textural appraisals, and the training of new employees.

In the screenable characterization of samples, a procedure for the sequence of testing and screening of samples should encompass the following phases. Under Phase I of the scheme, all samples would be characterized for (1) soil structure stability through measurement of hydraulic conductivity on a fragmented sample basis during the 6th and 24th hours and volume of wet settled floccules, (2) moisture retentivity at 15-bars pressure, (3) electrical conductivity of soil-water extract, and (4) pH in water and in 0.01 molar calcium chloride solution.

In the second phase, *selected* samples suspected through the testing results of Phase 1 to be salt affected should be characterized for electrical conductivity of the saturation extract and sodium adsorption ratio.

In the third phase, *selected* samples suspected through the testing results of Phases I and II to be salt affected with respect to sodium will be tested for either gypsum requirement or residual gypsum, depending on salinity levels and associated pH values. Residual gypsum will be estimated by measuring calcium plus magnesium in a 1:5 soil-water ratio extract and reported in milliequivalents per 100 grams.

Carbonate and bicarbonate were determined in saturation extract by titration with a weak acid solution and chloride was determined in saturation extract by Mohr volumetric method (Bower, C. A. and L. V. Wilcox, 1965. Soluble Salts. In C. A. Black, et al., Methods of Soil Analysis, Agronomy No. 9, American Society of Agronomy, 62-1.3.2.1, 62-3.4.2, and 62-3.5.2).

Cation-exchange capacity was measured at pH 8.2 by sodium saturation, washing with isopropyl alcohol, and extraction with ammonium acetate (Chapman, H. D., 1965. Cation Exchange Capacity. In C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy, 57-3).

Gypsum determined by increase in soluble calcium plus magnesium content upon dilution (Richards, et al., 1954. Diagnosis and Improvement of Saline and Alkali Soils. USDA Agricultural Handbook No. 60, 22c:104).

Hydraulic conductivity was measured on fragmented samples in plastic permeameters of 1-inch inside diameter under conditions of 2:1 constant head (USDI Bureau of Reclamation Instructions, 517.7.3).

Soil pH in 1:5 soil-water ratio suspension was measured by glass electrode and transistor voltmeter (Peech, Michael, 1965. Soil pH by Glass Electrode pH Meter. In C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy, 60-3.4.

Neutral salt exchange acidity and exchangeable aluminum were determined by extraction with 1N KCl and double titration with strong base and strong acid, respectively (McLean, E. O., 1965. Aluminum. In C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy, 67-3.2, 67-3.5).

Particle-size analysis was by the sieve and pipette method without removal of organic matter and insoluble carbonates using sodium metaphosphate for attaining dispersion (Day, Paul R., 1965. Particle Fractionation and Particle-Size Analysis. In C. A. Black, et al., Methods of Soil Analysis, Part 1, Agronomy No. 9, American Society of Agronomy, 43-4.3.1, 43-4.3.3, 43-4.3.5, and 43-4.3.6).

Soil pH in 1:2 soil 0.01M $CaCl_2$ solution ratio was measured by glass electrode and transistor voltmeter (Peech, Michael, 1965. Soil pH by Glass Electrode pH Meters. In C. A. Black, et al., Methods of Analysis, Part 2, Agronomy No. 9, American Society of Agronomy, 60-3.5).

Soluble salts were estimated by measuring electrical conductivity of saturation extract (Bower, C. A. and L. V. Wilcox, 1965. Soluble Salts. In C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy, 62-1.3.2.1 and 62-2.2).

Water retentivity of soil was measured at 15 bars pressure using ceramic plate or plastic membrane (Richards, L. A., 1965. Physical Condition of Water in Soil. In C. A. Black, et al., Methods of Soil Analysis, Part 1, Agronomy No. 9, American Society of Agronomy, 8-2.3).

Progress Report

Results of Weathering Tests Conducted on Core Samples from Fish Creek, Colorado

Laboratory weathering and outdoor exposure tests were conducted on overburden core samples from the Fish Creek, Colorado, study site. The purpose of these tests was to determine which materials would break down sufficiently to allow for their possible use as planting media in revegetation of strip-mined areas.

Test Procedures

Specimens for the laboratory weathering and outdoor exposure tests were cut from core samples submitted by regional personnel.

The reason for including outdoor exposure tests was to determine if any correlation could be drawn between this type of weathering and the laboratory weathering conditions.

A laboratory weathering cycle consisted of the following conditions:

1. 8 hours at 23.9 °C (75 °F), 100 percent relative humidity (wetting/thawing)

2. 16 hours (64 hours on weekends) at 37.8 °C (100 °F), 10 percent relative humidity (drying)

3. 8 hours at 23.9 °C (75 °F), 100 percent relative humidity (wetting)

4. 16 hours (64 hours on weekends) at minus 17.8 °C (0 °F) (freezing).

In this study, core specimens approximately 50 mm (2 in) in diameter by 50 mm (2 in) in length were used. For testing and handling, each core specimen was placed on a No. 10 mesh screen in a 400-ml plastic beaker.

Laboratory weathering tests were started on December 13, 1977, and 20 laboratory weathering cycles were completed on February 10, 1978. Outdoor exposure tests commenced on December 13, 1977, and were completed on December 12, 1978. During this one-year period, the specimens were subjected to 250 mm (10 in) of precipitation.

Test Results

Test results are summarized in Table F-1, and shown visually in Figures F-1 through F-3.

At the completion of the weathering tests, a percent breakdown value (%BD) was determined for the specimens. This value listed under the remarks column in the table was derived as follows:

$$\%BD = \frac{TW - IW}{TW} (100)$$

where

TW = total specimen weight

IW = weight of original specimen remaining intact after testing

Of the four samples tested, only the shale sample (F-4) broke down sufficiently to be considered for possible use as a planting media. The other three samples exhibited little or no breakdown at all.

Gradation of the weathered shale sample is shown below:

Sieve Size	Percent Retained on Screen Laboratory-weathered Specimen	Outdoor-weathered Specimen
No. 4	25.0	26.7
No. 8	27.8	23.8
No. 30	35.5	34.5
No. 50	5.5	5.4
No. 100	2.2	3.0
No. 200	1.3	1.8
Pan	2.7	4.8

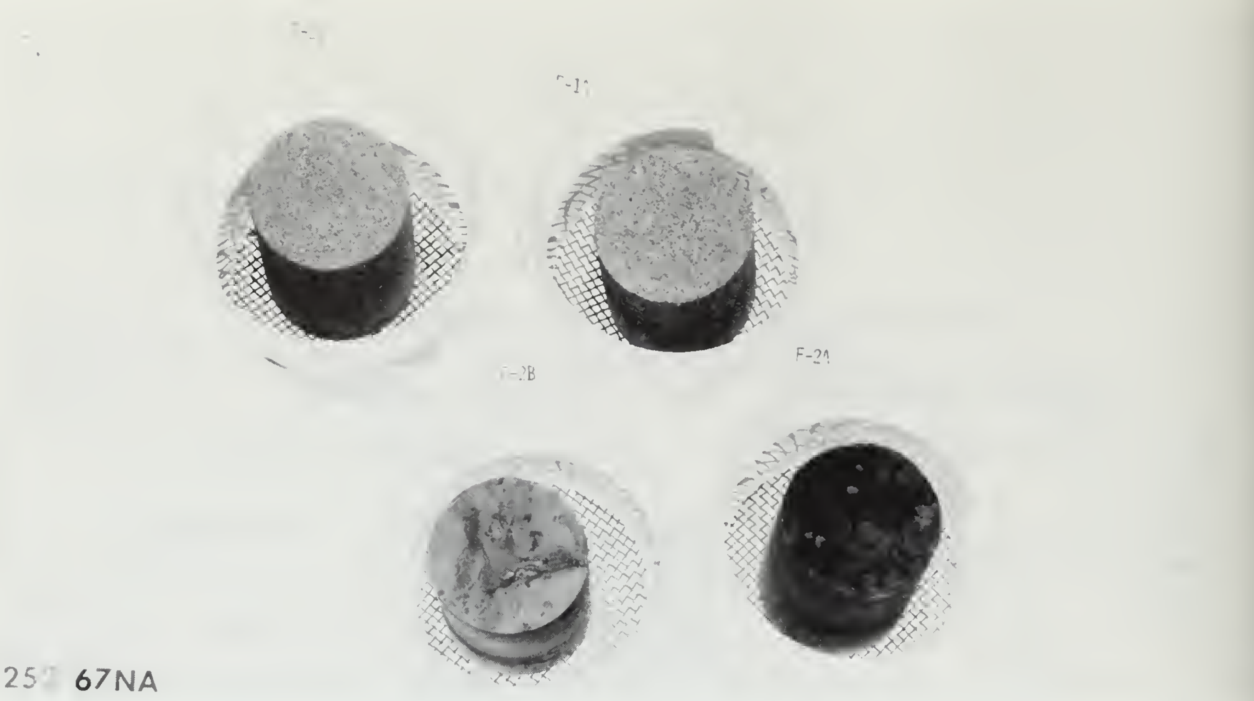
Table F-1

WEATHERING TESTS

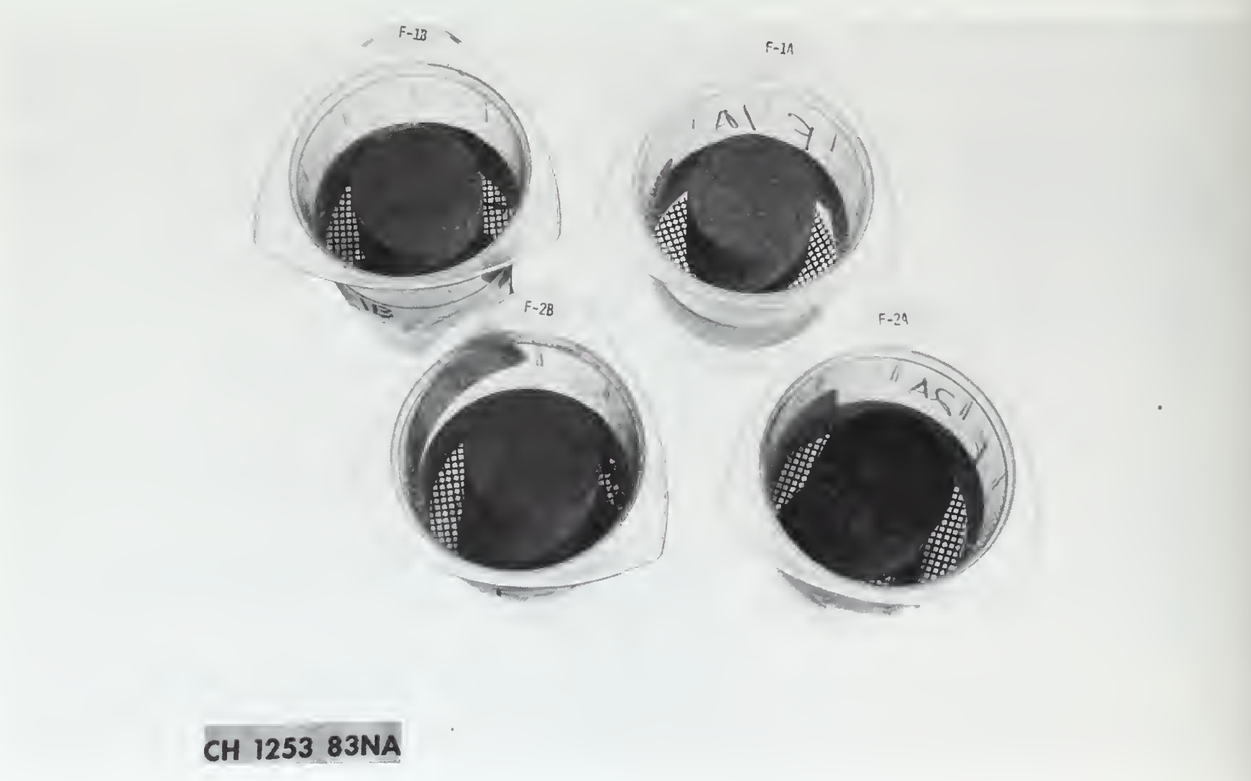
Core Samples From Fish Creek, Colorado

Sample I.D.	Remarks
Sandstone DH 3-10 248 Depth (ft) 47.0-52.5 (F-1)*	See Figures F-1 and F-3 Laboratory weathering: No change at 20 cycles. %BD = 0 Outdoor: No change at 1 year %BD = 0
Siltstone DH 3-20 256 Depth (ft) 97.0-106.0 (F-2)	See Figures F-1 and F-3 Laboratory weathering: No change in Specimen A at 20 cycles. %BD = 0 Outdoor: No change at 1 year. %BD = 0
Sandstone DH 3-26 262 Depth (ft) 140.0-151.5 (F-3)	See Figures F-2 and F-3 Laboratory weathering: No change in Specimen A at 20 cycles. %BD = 0 Outdoor: No change at 1 year. %BD = 0
Shale DH 4-16 169 Depth (ft) 80.0-90.3 (F-4)	See Figures F-2 and F-3 Laboratory weathering: Slaking in Specimen A at 5 cycles; Severe slaking at 20 cycles. %BD = 100 Outdoor: Severe slaking at 1 year. %BD = 100

* Laboratory sample number

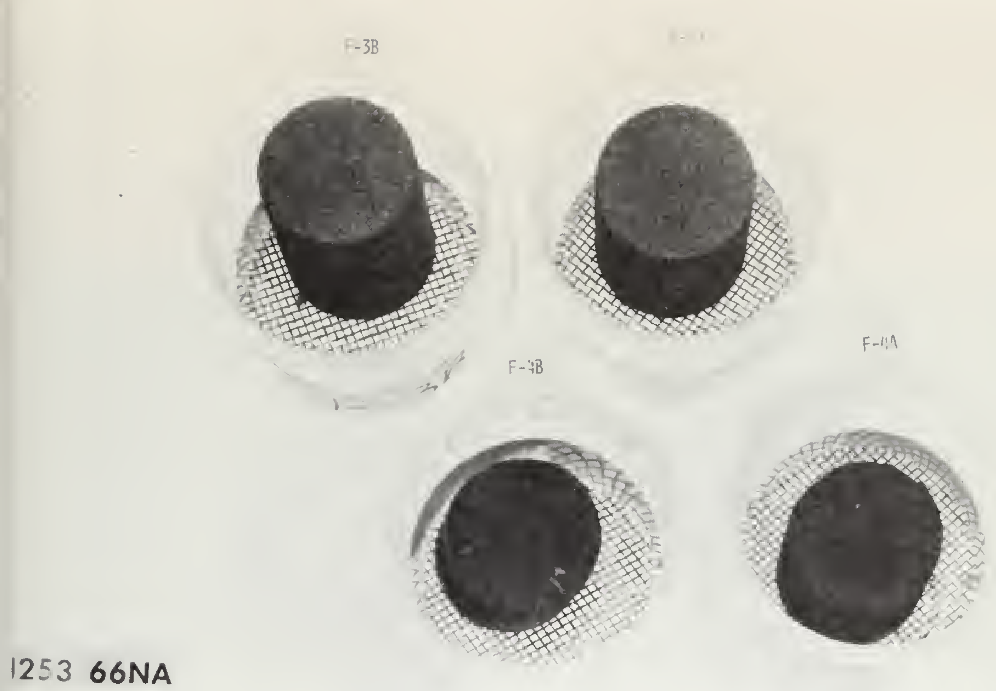


a. Original condition of test specimens.

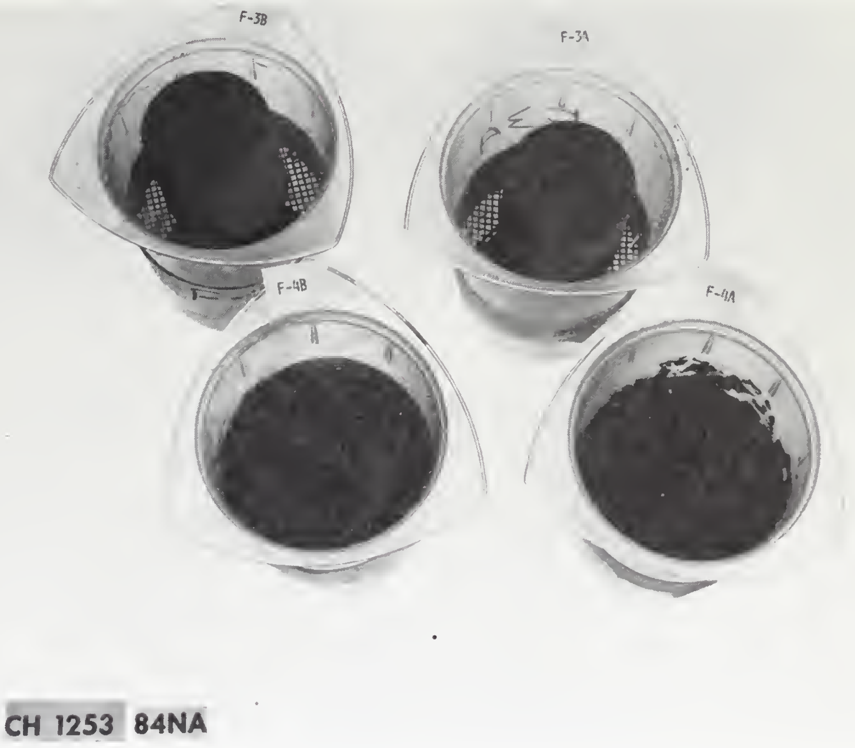


b. Condition of test specimens after weathering.

Figure F-1. - Results of weathering tests for sandstone sample F-1 and siltstone sample F-2. Specimens A subjected to 20 laboratory weathering cycles; specimens B subjected to 15 weeks of outdoor exposure.



a. Original condition of test specimens.



b. Condition of test specimens after weathering.

Figure F-2. - Results of weathering tests for sandstone sample F-3 and shale sample F-4. Specimens A subjected to 20 laboratory weathering cycles; specimens B subjected to 15 weeks of outdoor exposure.

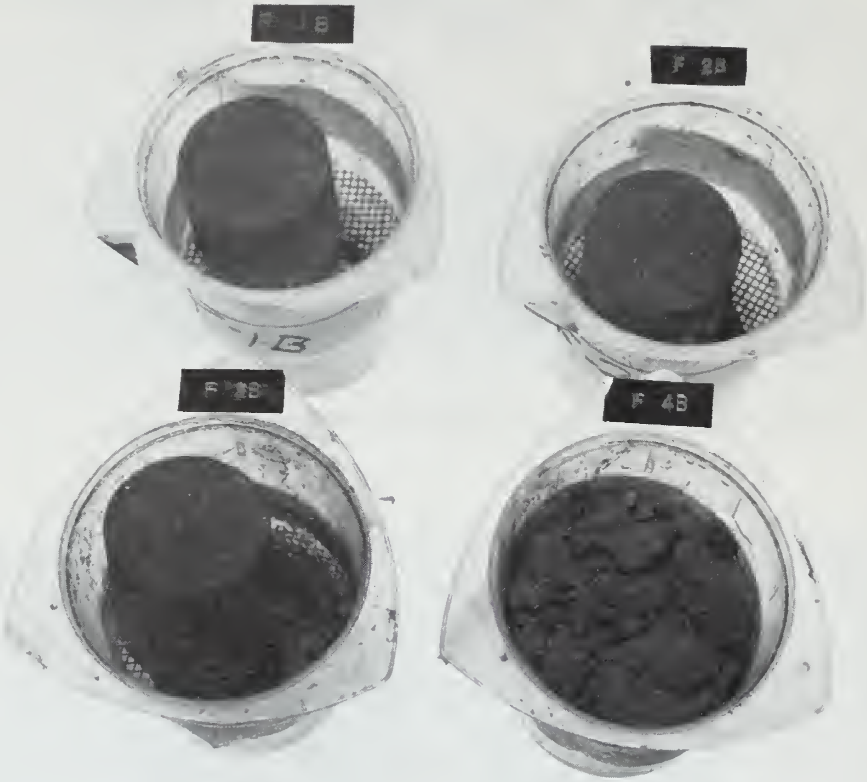


Figure F-3. - Results of one-year outdoor exposure tests.

RESULTS OF THE GREENHOUSE STUDY

The greenhouse and laboratory data are presented in this section on a site-by-site basis. The format of the discussion is as follows: 1) a brief discussion of the nature and purpose of the study on a site-by-site basis; 2) presentation of data in tabular form; and 3) an interpretive summary of the data.

As of the date of this publication, statistical analysis of the data is not available. The data are being statistically analyzed, using a cluster and discriminate analysis procedure. This procedure is being used to determine which soil characteristics are best correlated with relative productivity potential. The results of the statistical analyses will become part of a student's Master's degree program.

FISH CREEK SITE RESULTS

Studies Performed

1. A greenhouse study was conducted to determine the relative yield potential of western wheatgrass on the materials tested and to correlate yield response with soil and plant laboratory characterization data.
2. Pre-plant and post-harvest soil analyses for available P were conducted to determine the effect of added fertilizer P on the soil availability index for P.
3. The materials were consecutively cropped first to western wheatgrass and then corn to determine the relative yield potential between the two crops and to determine the relative uptake levels of selected elements between the crops.

The soil characterization data for the materials tested are shown in Table 4. Plant analyses data are shown in Table 4a. An interpretive summary and suitability ratings as plant growth media are shown in Table 4b.

Due to lack of funds, soil and plant laboratory analyses were performed only on selected samples.

Summary of Results

1. The application of 80 ppm of fertilizer P in the greenhouse raised the available P levels from low and very low to very high in samples which were tested. (See Table 4).
2. The remarks shown in Table 4b indicate that salinity and/or sodium are the major factors which limit the use of most of the materials as plant growth media. It appears that samples FC-2-15 and FC-2-14 offer the greatest potential. However, the

SAR levels are sufficiently high to warrant further study of the materials. Material No. FC-3-1 may be suitable, however, no laboratory data is available for this material because of insufficient sample.

3. Plant analyses data indicate that total P was below or near the critical level for both corn and western wheatgrass grown on many of the materials. This was also true for total K. These results suggest poor correlation between soil P levels and plant uptake. However, the above situation mainly occurred when yields were severely restricted by sodium and/or salinity.

4. Plant analyses data indicate a very strong sodium effect on the calcium and magnesium levels in the plant. These data are shown in Table 4c. Visual calcium deficiency symptoms were observed on the corn crop on materials FC-4-20, FC-4-25, FC-4-29 and FC-4-30. It is not known whether or not the high sodium found in many of the materials brought about low yields because of a poor soil physical condition or calcium and/or magnesium deficiencies, and/or P deficiencies and/or a combination of these factors.

5. There appears to be a very high relationship between increased sodium and/or salinity and decrease in yield.

Table 4. SOIL ANALYSES VS. RELATIVE YEILDS OF WESTERN WHEATGRASS AND CORN

Site: Fish Creek, Colorado

Sample Number	Depth (ft.)	Relative Yield % Western Wheat	Corn	SOIL TEST DATA Available P (ppm) Preplant	Post Plant	Available (ppm) Preplant Zn	Fe	Cu	Mn	K	pH 1:1	SAR 1:1	Elect. Cond. 1:1
Control	--	100	100										20.1
FC-2-15	99.3-107.0	92	113	--	--	.54	19.0	.32	2.30	32.5	--	8.63	14.6
FC-2-14	90.6-99.3	86	115	1	43	.56	39.30	.40	1.60	26.0	--	6.66	--
FC-3-1	0-5.0	85	--	--	--	--	--	--	--	--	--	--	--
FC-2-16	107.0-115.0	75	87	--		.48	12.50	.20	2.40	32.5	--	6.88	--
FC-1-6	25.0-30.0	69	28	--		5.00	90.0	3.60	54.00	130.0	--	3.79	--
FC-1-2	7.5-12.8	65	23	--		.54	15.00	1.60	11.80	200.0	--	1.84	--
FC-10-3	36-44 (in.)	58											
FC-1-5	20.3-25.0	56	13	--		5.30	118.0	3.20	36.40	130.0	--	4.54	--
FC-12-2	4-14 (in.)	53											
FC-1-1	0.0-5.0	39		--		1.04	34.00	.72	23.10	--	--	--	--
FC-4-4	10.0-17.5	37		--		3.04	20.00	2.24	8.60	150.0	--	4.21	--
FC-4-8	35.5-42.5	37		--		--	--	--	--	180.0	--	9.66	--
FC-2-12	69.3-76.8	36	45	2	52	2.52	295.20	2.28	8.20	100.0	--	29.92	--
FC-13-2	20-44 (in.)	35											
FC-2-13	76.8-84.0	33	29	1	53	2.64	146.0	2.40	10.60	2240.0	--	23.91	--
FC-2-1	0.0-3.0	27											
FC-4-21	125.3-131.0	27											
FC-4-33	200.1-204.4	26											
FC-4-7	28.5-35.5	25											
FC-4-6	21.5-28.5	24											
FC-1-4	13.6-18.7	18											
FC-4-14	65,5-72.0	18		3									
FC-4-15	72.0-80.0	17	-	--	--	6.10	80.0	2.44	9.80	305.0	--	48.0	--
FC-2-5	24.5-31.5	16	5	--	50	3.92	150.63	3.82	8.00	292.0	--	26.37	--
FC-4-9	42.5-51.5	16											
FC-4-12	58.3-64.1	16		--		8.40	60.0	4.40	12.60	280.0	--	50.27	--
FC-4-29	182.6-187.5	15	--	--	--	4.40	120.0	1.68	9.40	310.0	--	20.78	--
FC-4-18	98.0-107.8	14											
FC-4-20	115.0-125.3	13	4	--	--	5.30	63.0	3.64	7.60	350.0	--	37.60	--
FC-4-16	80.0-90.3	12											
FC-4-23	137.0-142.9	12											
FC-4-28	177.9-182.6	12											

Table 4. Fish Creek Site continued

		Relative Yield %		SOIL TEST DATA									
				Available P (ppm)		Available (ppm) Preplant							
Sample Number	Depth (ft.)	Western Wheat	Corn	Preplant	Post Plant	Zn	Fe	Cu	Mn	K	pH 1:1	SAR 1:1	Elect. Cond. 1:1
FC-2-6	31.5-38.5	11		4									
FC-4-17	90.3-98.0	11											
FC-4-19	107.8-115.0	11											
FC-2-7	38.5-45.5	10	11	2	41	3.76	124.0	3.48	12.80	292.0	--	56.89	--
FC-2-8	45.5-52.5	10	5	--	46	4.60	148.0	5.36	16.60	292.0	--	64.15	--
FC-2-10	57.5-63.0	10	5	--	49	5.90	80.40	2.72	12.60	262.5	--	63.19	--
FC-2-11	63.0-69.3	10	7	2	50	4.90	125.0	3.60	12.60	296.0	--	24.73	--
FC-2-9	52.5-57.5	8	4	--	53	6.40	75.0	7.60	25.0	275.0	--	56.98	--
FC-4-10	51.5-56.3	8		51		3.52	150.63	2.92	7.0	305.0	--	41.84	--
FC-4-22	131.0-137.0	8		--		--	99.0	3.80	9.20	230.0	--	47.69	--
FC-4-24	142.9-150.0	8											
FC-4-25	150.0-160.3	7	10	--	--								
FC-4-30	187.5-192.2	7		--		6.20	164.0	3.72	12.0	285.0	--	58.46	--
FC-4-27	168.0-177.9	5											
FC-4-26	160.3-168.0	4		--		5.0	131.25	2.40	7.0	280.0	--	54.15	--

Table 4a. RELATIVE YEILD VS. PLANT ANALYSES DATA

Site: Fish Creek, Colorado

		Relative Yield %		Plant Analyses Data											
				Western Wheat Grass						Corn					
Sample Number	Depth (ft.)	Western Wheat	Corn	Fe ppm	Zn ppm	Mn ppm	Cu ppm	P %	K %	Fe ppm	Zn ppm	Mn ppm	Cu ppm	P %	K %
Control	---	100	100	64.66	31.54	39.43	7.25	.57	1.47						
FC-2-15	99.3-107.0	92	113							79.0	17.75	47.50	4.23	.20	2.88
FC-2-14	90.6-99.3	86	115							100.0	18.50	48.75	5.00	.17	.81
FC-2-16	107.0-115.0	75	87	77.36	26.63	62.07	5.04	.37	2.11	218.0	30.75	91.25	12.50	.14	1.13
FC-1-6	25.0-30.0	69	28	37.57	---	137.15	10.13	---	1.77	95.74	91.84	254.99	146.71	.09	3.06
FC-1-2	7.5-12.8	65	23	98.24	17.03	72.04	12.01	.31	2.67	130.0	18.0	145.0	11.25	.17	2.26
FC-1-5	20.3-25.0	56	13	54.61	33.98	83.73	6.07	---	1.53	91.26	75.39	293.63	8.33	.13	2.98
FC-1-1	0.0-5.0	39		84.58	25.56	46.99	3.38	.38	2.03						
FC-4-4	10.0-17.5	37		66.49	20.21	73.13	8.24	.19	2.18						
FC-4-8	35.5-42.5	37		88.34	36.67	83.34	8.89	---	2.78						
FC-2-12	69.3-76.8	36	45	79.38	32.43	69.25	15.88	.25	2.43	76.18	63.87	150.10	7.39	.09	1.84
FC-2-13	76.8-83.0	33	29	81.78	43.93	102.81	9.35	.26	2.76	71.20	74.64	140.02	5.91	.13	2.23
FC-4-15	72.0-80.0	17	7							107.14	59.59	113.99	7.59	.16	1.08
FC-2-5	24.5-31.5	16	5	70.00	34.0	62.50	7.50	---	1.30	173.04	83.05	235.26	8.64	.15	1.12
FC-4-9	42.5-51.5	16		114.58	45.83	93.75	19.79	.07	1.90						
FC-4-29	182.6-187.5	15		97.51	40.68	9.53	9.53	---	1.95						
FC-4-20	115.0-125.3	13	4	87.84	45.95	81.08	11.49	.13	1.35	382.54	49.37	68.98	11.17	.23	.82
FC-2-7	38.5-45.5	10	11	55.88	26.47	72.06	7.35	.10	1.10	132.05	29.56	71.72	3.78	.15	.35
FC-2-8	45.5-52.5	10	5	173.91	39.13	86.96	29.35	---	1.74	245.43	40.26	100.33	7.40	.17	.53
FC-2-10	57.5-63.0	10	5	88.89	25.93	50.0	8.33	.07	.76	113.08	56.69	134.92	9.85	.16	.55
FC-2-11	63.0-69.3	10	7	113.64	45.46	106.06	10.61	.15	1.63	98.16	66.24	127.63	6.45	.14	.42
FC-2-9	52.5-57.5	8	4	33.09	7.35	13.24	3.31	.07	.31	183.47	47.80	106.05	9.29	.21	.58
FC-4-10	51.5-56.3	8		205.88	64.71	88.24	24.26	.09	1.25						
FC-4-22	131.0-137.0	8		151.52	30.30	63.64	10.61	.11	1.25						
FC-4-25	150.0-160.3	7	10	300.0	80.0	130.0	32.50	.14	2.88	279.48	53.67	79.12	9.34	.17	1.01
FC-4-30	187.5-192.2	7		160.71	64.29	28.57	28.57	.09	1.70						
FC-4-26	160.3-168.0	4		250.0	53.33	21.67	21.67	.18	2.67						

#2

#3

Table 4b. Interpretive Summary for all Fish Creek Materials

Sample No.	% Relative Yield Western Wheat	% Relative Yield Corn	Remarks	Suitability Rating
Control	100	100	No apparent problem	
FC-2-15	92	113	SAR is moderately high; no salt crusting observed.	Potentially suitable
FC-2-14	86	115	SAR is marginally high; no salt crusting observed.	Potentially suitable
FC-3-1	85	---	No lab data available; low field capacity. Slight salt crusting observed.	Potentially suitable
FC-2-16	75	87	SAR is marginally high; slight salt crusting. Low field capacity.	Unsuitable
FC-1-6	69	28	SAR is marginally high; slight salt crusting. Very low field capacity. P level in corn below considered critical level.	Unsuitable
FC-1-2	65	23	Slight to moderate salt crusting; no other apparent problem	Unsuitable
FC-10-3	58	---	Slight to moderate salt crusting; no other apparent problem. No laboratory data available.	Unsuitable
FC-1-5	56	13	SAR is marginally high; field capacity very low; slight salt crusting observed.	Unsuitable
FC-12-2	53	---	Slight salt crusting observed; no laboratory data available.	Unsuitable
FC-1-1	39	---	Slight salt crusting observed: no laboratory data available.	Unsuitable
FC-4-4	37	---	Slight salt crusting observed; SAR is in marginal range.	Unsuitable
FC-4-8	37	---	SAR high; very low field capacity; slight salt crusting observed.	Unsuitable
FC-2-12	36	45	SAR high; slight salt crusting; very low field capacity.	Unsuitable
FC-13-2	35	---	Slight salt crusting. No laboratory data available.	Unsuitable
FC-2-13	33	29	SAR high; salt crusting moderately severe; very low field capacity.	Unsuitable
FC-2-1	27	---	Slight to moderate salt crusting: no laboratory data available.	Unsuitable
FC-4-21	27	---	Slight to moderate salt crusting; no laboratory data available.	Unsuitable
FC-4-33	26	---	Slight to moderate salt crusting; no laboratory data available.	Unsuitable
FC-4-7	25	---	Slight to moderate salt crusting; no laboratory data available.	Unsuitable
FC-4-6	24	---	Slight to moderate salt crusting, no laboratory data available.	Unsuitable
FC-1-4	18	---	Moderate to severe salt crusting: no laboratory data available.	Unsuitable
FC-4-14	18	---	Moderate to severe salt crusting; no laboratory data available.	Unsuitable
FC-4-15	17	7	SAR high. Moderate to severe salt crusting. Very low field capacity.	Unsuitable
FC-2-5	16	5	SAR high. Moderate salt crusting. Low field capacity.	Unsuitable
FC-4-9	16	---	Moderate salt crusting. P level in western wheatgrass was very low.	Unsuitable
FC-4-12	16	---	SAR high: moderate to severe salt crusting.	Unsuitable
FC-4-29	15	---	SAR high: moderate to severe salt crusting. Very low field capacity.	Unsuitable
FC-4-18	14	---	Severe salt crusting. No laboratory data available.	Unsuitable
FC-4-20	13	4	SAR high; moderate to severe salt crusting.	Unsuitable
FC-4-16	12	---	Moderate salt crusting; very low field capacity. No laboratory data available.	Unsuitable
FC-4-23	12	---	Moderate salt crusting: very low field capacity. No laboratory data available.	Unsuitable
FC-4-28	12	---	Moderate salt crusting; very low field capacity. No laboratory data available.	Unsuitable
FC-2-6	11	---	Slight salt crusting; low field capacity. No laboratory data available.	Unsuitable
FC-4-17	11	---	Moderate to severe salt crusting; very low capacity. No laboratory data available.	Unsuitable
FC-4-19	11	---	Severe salt crusting: low field capacity. No laboratory data available.	Unsuitable

Sample No.	Relative Yield Western Wheat	Corn	Remarks	Suitability Rating
FC-2-7	10	11	SAR high; moderate to severe salt crusting; low field capacity.	Unsuitable
FC-2-8	10	5	SAR high; moderate to severe salt crusting; low field capacity.	Unsuitable
FC-2-10	10	5	SAR high; severe salt crusting; low field capacity.	Unsuitable
FC-2-11	10	7	SAR high; severe salt crusting; low field capacity.	Unsuitable
FC-2-9	8	4	SAR high; severe salt crusting; low field capacity.	Unsuitable
FC-4-10	8	--	SAR high; severe salt crusting; low field capacity.	Unsuitable
FC-4-22	8	--	SAR high; slight salt crusting; low field capacity.	Unsuitable
FC-4-24	8	--	Moderate to severe salt crusting; low field capacity; no laboratory data.	Unsuitable
FC-4-25	7	--	Moderate to severe salt crusting; very low field capacity; no laboratory data.	Unsuitable
FC-4-30	7	--	SAR high; severe salt crusting; low field capacity.	Unsuitable
FC-4-27	5	--	Moderate to severe salt crusting; very low field capacity; no laboratory data.	Unsuitable
FC-4-26	4	--	SAR high; severe salt crusting; very low field capacity.	Unsuitable

Table 40. Soil and Plant Ca, Mg and Na Levels, Fish Creek Site, Colorado

	Soil Data			Plant Analyses					
	NH_4AC Extractable			Na %		Total Mg %		Ca %	
Sample No.	Ca %	Mg %	Na ppm	Western Wheat	Corn	Western Wheat	Corn	Western Wheat	Corn
FC-1-1	--	--	--	.006	--	.16	--	.49	--
FC-1-2	.200	.023	175	.013	.01	.26	.70	.41	.90
FC-1-4	--	--	--	--	--	--	--	--	--
FC-1-5	.300	.038	500	--	.34	.16	.89	.33	1.26
FC-1-6	.2800	.042	420	.475	.44	.30	.77	.63	1.50
FC-4-17	--	--	--	--	--	--	--	--	--
FC-4-18	--	--	--	--	--	--	--	--	--
FC-4-19	--	--	--	--	--	--	--	--	--
FC-4-20	.140	.028	3050	.554	6.79	.18	.35	.17	.48
FC-4-21	--	--	--	--	--	--	--	--	--
FC-4-22	.150	.024	3900	.379	--	.13	--	.14	--
FC-4-23	--	--	--	--	--	--	--	--	--
FC-4-24	--	--	--	--	--	--	--	--	--
FC-4-25	--	--	--	.900	5.84	.26	.39	.35	.38
FC-4-26	.190	.020	4800	[illegible]	--	.22	--	.28	--
FC-4-27	--	--	--	--	--	--	--	--	--
FC-4-28	--	--	--	--	--	--	--	--	--
FC-4-29	.210	.230	3000	--	--	.16	--	.21	--
FC-4-30	.210	.025	5500	1.018	--	.20	--	.25	--
FC-4-33	--	--	--	--	--	--	--	--	--
FC-4-4	.670	.184	780	.096	--	.27	--	.40	--
FC-4-6	--	--	--	--	--	--	--	--	--
FC-4-7	--	--	--	--	--	--	--	--	--
FC-4-8	.160	.052	900	--	--	.20	--	.31	--
FC-4-9	--	--	--	.562	--	.24	--	.29	--
FC-4-10	.160	.027	3350	.941	--	.24	--	.32	--
FC-4-12	.260	.056	5600	--	--	--	--	--	--
FC-4-14	--	--	--	--	--	--	--	--	--
FC-4-15	.150	.032	4050	--	3.64	--	.29	--	.34
FC-4-16	--	--	--	--	--	--	--	--	--
FC-2-14	.120	.060	450	--	.41	--	.44	--	.46

Table 4C (continued). Soil and Plant Ca, Mg and Na Levels, Fish Creek Site, Colorado

	Soil Data			Plant Analyses					
	NH_4AC Extractable			Na %		Total Mg %		Ca %	
Sample No.	Ca %	Mg %	Na ppm	Western Wheat	Corn	Western Wheat	Corn	Western Wheat	Corn
FC-2-15	.100	.007	540	--	.47	--	.47	--	.39
FC-2-16	.150	.008	520	.607	.41	.20	.49	.49	.53
FC-2-1	--	--	--	--	--	--	--	--	--
FC-2-5	.220	.06	2800	.100	5.94	.13	.84	.18	1.17
FC-2-6	--	--	--	--	--	--	--	--	--
FC-2-7	.150	.032	4800	.221	3.62	.12	.25	.13	.37
FC-2-8	.120	.026	4850	--	4.91	.15	.39	.17	.32
FC-2-9	.150	.026	4700	.735	5.69	.04	.43	.08	.36
FC-2-10	.200	.029	5900	.278	4.69	.09	.38	.09	.28
FC-2-11	.170	.024	4250	.250	4.12	.20	.22	.26	.29
FC-2-12	.190	.010	1100	.600	.95	.16	.36	.30	.45
FC-2-13	.220	.019	2250	.689	1.78	.16	.30	.30	.33
FC-3-1	--	--	--	--	--	--	--	--	--
FC-10-3	--	--	--	--	--	--	--	--	--
FC-12-2	--	--	--	--	--	--	--	--	--
FC-13-2	--	--	--	--	--	--	--	--	--

GENERAL CONCLUSIONS

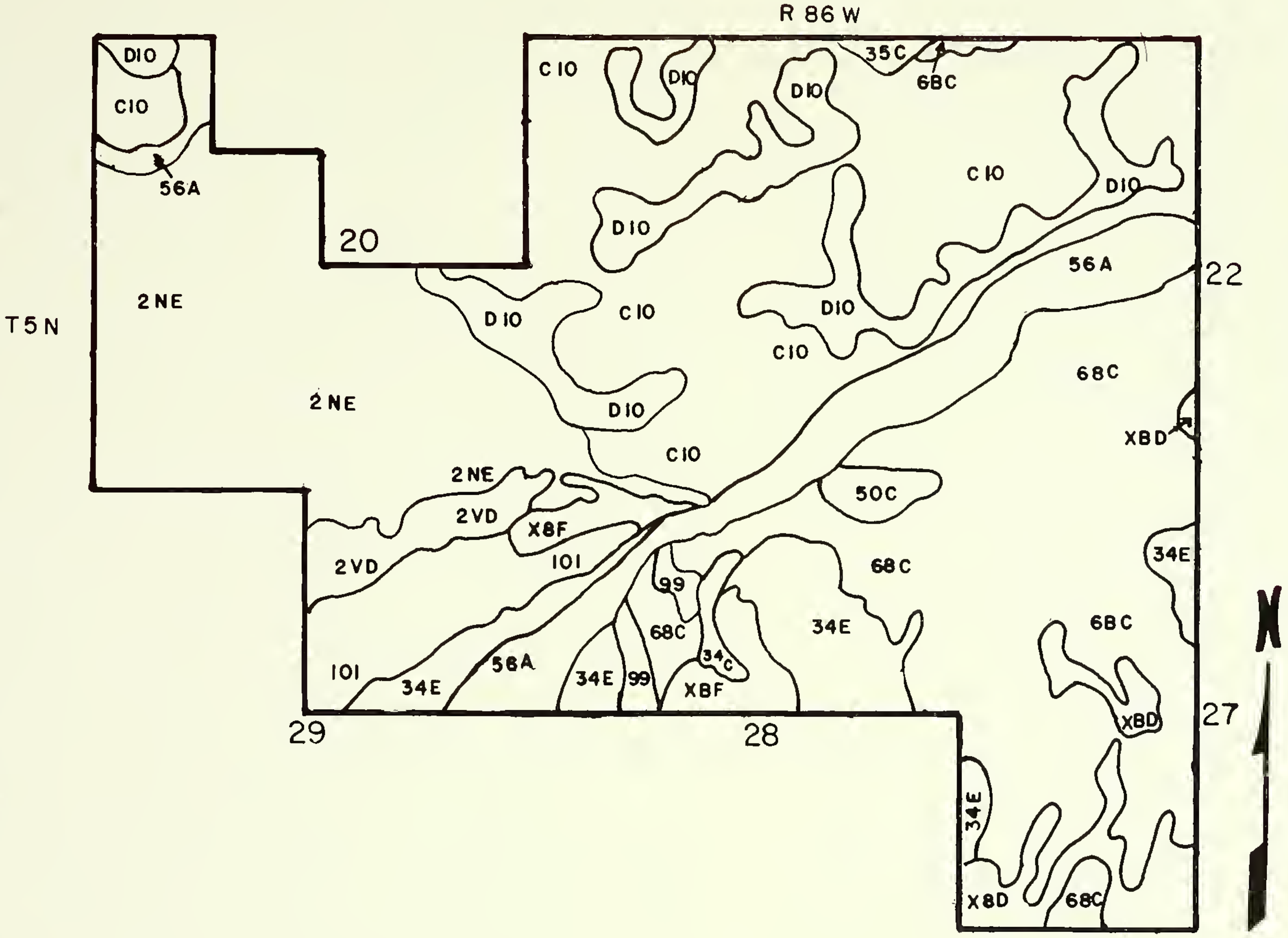
In general, the overall results of this study can be summarized as follows:

1. The effects of sodium and/or salinity on yield correlated well with soil test data.
2. Available phosphorus was low to very low in nearly all materials tested. The application of 80 ppm P appeared to raise the available P level in the material to a sufficient level. It is important to note that the added P was incorporated into the soil.
3. Soil zinc and copper levels were low (based on response by agronomic crops) in a large percentage of the materials. These low levels in the soil were, in most cases, reflected in the level found in the plants. There is some evidence that low soil zinc levels affected corn yields. This same evidence does not exist with respect to western wheatgrass. On the other hand, the persistence of lower zinc levels in the plants raises the question of the nutrient quality of forage grown.
4. Low field capacity may have created a water management problem in the greenhouse which in turn affected yield. This characteristic raises the question of a high erosion potential associated with these materials.
5. In some cases the greenhouse and laboratory characterization data obtained were not adequate for explaining some of the yield and other responses obtained in plant growth. This indicates that factors other than those observed are limiting productivity potential. This reflects the importance of greenhouse studies

in stratifying materials relative to the need for further investigations. Without greenhouse data, the interpretive process will be more costly and less reliable.

7. The results obtained strongly suggest that studies are needed to evaluate the effects of weathering and crop environment on the chemical and physical properties of geologic materials. This is evident from the fact that in many cases post-harvest soil test data related better to yield response than did pre-plant soil data.
8. It appears that the factors which determine yield or productivity potential on geologic materials are very complex, particularly when one considers the unavailability of soil-plant relationship data as it applies to mined land reclamation situations.
9. The results also indicate that more emphasis is needed in evaluating the effect of physical properties on yield potential.

In summary, the results of this study appear to raise as many questions as can be answered. The data do, however, point out the need for and potential of establishing a screenable testing program which can minimize the amount of resources needed for determining the suitability of materials as plant growth media and at the same time allow for credible and reliable interpretations to be made.



1 1/2 0 1 MILE

SCALE 1: 24 000

MAPPING UNIT NUMBER	NAME	RANGE OF SLOPE
2NE	UNNAMED-COCHETOPA COMPLEX.	12 to 25 %
2VD	ROUTT LOAM.	3 to 5 %
X8D	WINEVADA-SPLITRO COMPLEX.	3 to 25 %
XBF	WINEVADA-SPLITRO COMPLEX.	25 to 65 %
C10	BINCO SILTY CLAY LOAM.	3 to 12 %
D10	BINCO SILTY CLAY LOAM.	12 to 25 %
34 C	COUTIS FINE SANDY LOAM.	3 to 12 %
34 E	COUTIS FINE SANDY LOAM.	12 to 25 %
35 C	AABERG SILTY CLAY.	3 to 12 %
50 C	COCHETOPA LOAM.	3 to 12 %
56 A	TONKS LOAM.	0 to 5 %
68 C	UNNAMED SANDY LOAM.	3 to 12 %
99	CRYOBOROLLS ROCK OUTCROP.	
101	TORRIORTHENTS ROCK OUTCROP COMPLEX, VERY STEEP.	

ALWAYS THINK SAFETY

FISH CREEK STUDY SITE

COMPOSITE SOIL INVENTORY

DESIGNED B.L.M. FIELD APPROVAL
DRAWN L. PETERSON TECHNICAL APPROVAL
CHECKED T. CAPPELLUCCI APPROVED

DENVER

2NE - Unnamed-Cochetopa complex, 12 to 25 percent slopes

These moderately deep and deep soils are on strongly sloping to moderately steep mountain sideslopes at elevations of 6,800 to 8,000 feet. These soils formed in material weathered from sandstone and shale. The average annual precipitation is about 18 to 22 inches. Unnamed (2NE) loams make up about 50 percent of this unit, and Cochetopa makes up about 35 percent; small areas of Splitro soils and Rock outcrop are included in this unit.

Typically, the Unnamed (2NE) soil has a dark grayish brown loam surface layer about 10 inches thick. The subsoil is yellowish brown heavy clay loam about 10 inches thick overlying fractured hard sandstone.

Permeability of the Unnamed (2NE) soil is slow. Available water capacity is moderate. Surface runoff is medium and erosion hazard is high from water.

Typically, the Cochetopa soil has a dark grayish brown loam surface layer about 18 inches thick. The subsoil is yellowish brown clay loam about 27 inches thick. The substratum is yellowish brown clay loam extending to 60 inches or more.

Permeability of the Cochetopa soil is slow. Available water capacity is high. Surface runoff is medium and erosion hazard is high from water.

Most of the acreage is rangeland and used for livestock grazing and wildlife habitat.

2VD - Routt loam, 3 to 25 percent slopes

This is a deep, well-drained soil on gently sloping to moderately steep benches and mountain sideslopes at elevations of 7,000 to 8,200 feet. It formed in mixed colluvium and residuum. The average annual precipitation is 20 to 25 inches.

Included in this unit are Coutis fine sandy loam, Unnamed (2) loam, and Cochetopa fine sandy loam.

Typically the surface layer is very dark grayish brown to brown loam about 26 inches thick. The upper subsoil layer is yellowish brown clay loam about 12 inches thick, with light gray unncoated sand grains occurring on the faces of peds. The lower subsoil is yellowish brown and light yellowish brown heavy silty clay loam extending to 60 inches or more.

Permeability is very slow. Effective rooting depth is 60 inches or more. Available water capacity is high. Surface runoff is medium. Erosion hazard is high from water.

Most of this unit is native rangeland used for livestock grazing and wildlife habitat. Some of the unit is used for pasture or dryland farming.

X8D - Winevada-Spiltro complex, 3 to 25 percent slopes

These moderately deep and shallow soils are on gently sloping to moderately steep mountain sideslopes at elevations of 6,900 to 8,400 feet. The average annual precipitation is 20 to 25 inches.

The Winevada soils occupy lower sideslopes and concave areas and make up 60 percent of the unit. The Splitro soils occupy upper sideslopes and ridgecrests and make up about 30 percent of the unit. Small areas of Coutis fine sandy loam and Unnamed (68) sandy loam make up the other 10 percent.

Typically the Winevada soils have a very dark gray fine sandy loam upper surface layer about 4 inches thick. The lower surface layer is dark grayish brown sandy clay loam about 24 inches thick over fractured hard sandstone.

Permeability of the Winevada soils is moderate. Effective rooting depth ranges from 20 to 40 inches. Available water capacity is low. Surface runoff is slow. Erosion hazard is high from water.

Typically the Splitro soils have a very dark grayish brown and dark grayish brown sandy loam surface layer 18 inches thick over fractured hard sandstone.

Permeability of the Splitro soils is moderately rapid. Effective rooting depth ranges from 10 to 20 inches. Available water capacity is very low. Surface runoff is slow, erosion hazard is moderate from water.

Most of this unit is native rangeland and used for livestock grazing and wildlife habitat.

X8F - Winevada-Splitro complex, 25 to 65 percent slopes

These moderately deep and shallow soils are on moderately steep and very steep mountain sideslopes at elevations of 6,900 to 8,400 feet. The average annual precipitation is 20 to 25 inches.

The Winevada soils occupy lower sideslopes and concave areas and occupy 60 percent of the unit. The Splitro soils occupy upper sideslopes and ridgecrests and make up about 30 percent of the unit. Small areas of Coutis fine sandy loam and Rock Outcrop make up the other 10 percent.

Typically the Winevada soil has a very dark gray fine sandy loam upper surface layer about 4 inches thick. The lower surface layer is dark grayish brown sandy clay loam about 24 inches thick over fractured hard sandstone.

Permeability of the Winevada soils is moderate. Effective rooting depth ranges from 20 to 40 inches. Available water capacity is low. Surface runoff is medium. Erosion hazard is high from water.

Typically the Splitro soils have a very dark grayish brown and dark grayish brown sandy loam surface layer about 18 inches thick over fractured hard sandstone.

Permeability of the Splitro soils is moderately rapid. Effective rooting depth ranges from 10 to 20 inches. Available water capacity is very low. Surface runoff is medium. Erosion hazard is high from water.

Most of this unit is native rangeland used for livestock grazing and wildlife habitat.

C10 - Binco silty clay loam, 3 to 12 percent slopes

This is a deep, well-drained soil on gently to strongly sloping benches and ridges at elevations of 6,800 to 8,200 feet. It formed in material weathered from shale. The average annual precipitation is 18 to 22 inches.

Included in this unit are Unnamed (69) loam and Aaberg silty clay.

Typically the surface layer is grayish brown silty clay loam about 4 inchs thick. The subsoil is grayish brown clay about 22 inches thick, and the substratum is light brownish gray clay extending to 60 inches or more.

Permeability is very slow. Effective rooting depth is 60 inches. Available water capacity is moderate. Surface runoff is medium, erosion hazard is moderate from water.

Most of this unit is used for dryland farming. Some areas are native rangeland and used for livestock grazing.

D10 - Binco silty clay loam, 12 to 25 percent slopes

This is a deep, well-drained soil on strongly sloping to moderately steep ridges and mountain sideslopes at elevations of 6,800 to 8,200 feet. It formed in material weathered from shale. The average annual precipitation is 18 to 22 inches.

Included in this unit are Unnamed (69) loam and Aaberg silty clay.

Typically the surface layer is grayish brown silty clay loam about 4 inches thick. The subsoil is grayish brown clay about 22 inches thick, and the substratum is light brownish gray clay extending to 60 inches or more.

Permeability is very slow. Effective rooting depth is 60 inches. Available water capacity is moderate. Surface runoff is rapid, erosion hazard is moderate from water.

Most of this unit is native rangeland and used for livestock grazing. Some areas are used for dryland farming.

34C - Coutis fine sandy loam, 3 to 12 percent slopes

This is a deep, somewhat excessively drained soil on gently to strongly sloping mountain sideslopes at elevations of 6,900 to 8,400 feet. It formed in residuum weathered from sandstone. The average annual precipitaton is 20 to 25 inches.

Included in this unit are small areas of Skylick loam, Unnamed (70) sandy loam, and Winevada fine sandy loam.

Typically the surface layers are dark grayish brown and brown fine sandy loams about 37 inches thick. The lower part of the surface layer is a pale brown fine sandy loam about 8 inches thick. The substratum is light yellowish brown fine sandy loam extending to 60 inches or more.

Permeability is moderate. Effective rooting depth is 60 inches or more. Available water-holding capacity is moderate. Surface runoff is slow, erosion hazard is high from wind and low from water.

Most of this unit is in native rangeland and used for livestock grazing and wildlife habitat. Some areas are used for dryland crops.

34E - Coutis fine sandy loam, 12 to 25 percent slopes

This is a deep, somewhat excessively drained soil on strongly sloping to moderately steep mountain sideslopes at elevations of 6,900 to 8,400 feet. It formed in residuum weathered from sandstone. The average annual precipitation is 20 to 25 inches.

Included in this unit are areas of Unnamed (70) sandy loam, Winevada fine sandy loam, and Skylick loam.

Typically the surface layers are dark grayish brown and brown fine sandy loams about 37 inches thick. The lower part of the surface layer is a pale brown fine sandy loam about 8 inches thick. The substratum is light yellowish brown fine sandy loam extending to 60 inches or more.

Permeability is moderate. Effective rooting depth is 60 inches or more. Available water capacity is moderate. Surface runoff is slow, erosion hazard is high from wind and medium from water.

Most of this unit is in native rangeland and used for livestock grazing and wildlife habitat.

35C - Aaberg silty clay, 3 to 12 percent slopes

This is a moderately deep, well-drained soil on gently to strongly sloping hillsides at elevations of 6,800 to 8,400 feet. It formed in material weathered from shale and siltstone. The average annual precipitation is about 18 to 22 inches.

Small areas of Bulkley silty clay loam are included in this mapping unit.

Typically the surface layer is grayish brown silty clay about 2 inches thick. The substratum is light yellowish brown silty clay about 3 inches thick and overlies soft shale bedrock at a depth of 35 inches.

Permeability is very slow. Available water capacity is low. Effective rooting depth is 20 to 40 inches. Surface runoff is medium and erosion hazard is moderate from water.

Most of the acreage is dry cropland with small areas of rangeland. The rangeland is used for livestock grazing and wildlife habitat.

50C - Cochetopa loam, 3 to 12 percent slopes

This is a deep, well-drained soil on gently to moderately sloping mountain sideslopes and benches at elevations of 7,000 to 8,500 feet. It formed in material weathered from shale. The average annual precipitation is about 18 to 22 inches.

Small areas of Routt loam and Unnamed (2) loam are included in mapping.

Typically the surface layer is dark grayish brown loam about 18 inches thick. The subsoil is yellowish brown clay loam about 29 inches thick. The substratum is yellowish brown clay loam to 60 inches or more. Permeability is slow. Available water capacity is high. Efective rooting depth is 60 inches or more. Surface runoff is slow and erosion hazard is slight.

Most of the acreage is rangeland and is used for livestock grazing and wildlife habitat. Small areas are dry cropland.

56A - Tonks loam, 0 to 5 percent slopes

This is a deep, poorly drained soil on nearly level to gently sloping flood plains at elevations of 6,700 to 7,500 feet. It formed in mixed alluvium. The average annual precipitation is about 18 inches.

Small areas of Foxcreek loam and Gapo clay loam are included in this mapping unit.

Typically the surface layer is a grayish brown loam about 12 inches thick. The underlying material is light brownish gray sandy clay loam to 60 inches or more. Depth to a seasonal high water table is about 12 inches.

Permeability is moderate. Effective rooting depth is 20 to 30 inches. Available water capacity is high. Surface runoff is slow or ponded, and the erosion hazard is slight from water.

All of the acreage is hayland. Cold climate and short growing season limit production of introduced grasses and preclude its use as cropland.

68C - Unnamed sandy loam, 3 to 12 percent slopes

This is a deep, well-drained soil on gently to strongly sloping mountain sideslopes at elevations of 6,900 to 8,400 feet. It formed in material weathered from sandstone. The average annual precipitation is 20 to 25 inches.

Included in this unit are small areas of Skylick loam.

Typically the surface layer is dark brown sandy loam about 10 inches thick. The upper subsoil layer is dark brown sandy clay loam about 14 inches thick, the lower subsoil is yellowish brown sandy clay loam about 6 inches thick, and the substratum is yellowish brown sandy clay loam extending to 60 inches or more.

Permeability is moderate. Effective rooting depth is 60 inches or more. Available water capacity is moderate. Surface runoff is slow, erosion hazard is moderate from water.

Most of this unit is used for dryland farming. Some areas are in native rangeland and used for livestock grazing and wildlife habitat. Minor acreages are irrigated and used for hay production.

99 - Cryoborolls-Rock outcrop

The Cryoboroll portion has moderate to rapid permeability and the available water capacity ranges from low to high. The effective rooting depth is from 10 to 60 inches or more. Surface runoff is medium and erosion hazard is slight to moderate from wind and high from water.

This complex is subject to slips and shows evidence of old slump areas.

Most of the Cryoboroll portion is in native range and used for grazing.

101 - Torriorthents-Rock outcrop complex, very steep

This unit is on very steep mountain sideslopes at elevations of 6,300 to 8,400 feet. Average annual precipitation is 15 to 20 inches. Torriorthents make up 50 percent and Rock outcrop makes up 40 percent of this unit. Small areas of Unnamed (62) sandy loam and Lymanson loam make up the remaining 10 percent.

Torriorthents are shallow to deep, well-drained soils that formed in material weathered from shale and sandstone. Surface layers are light colored stony or cobbly sandy loams to clay loams. The underlying material is stony or cobbly clay loam to sandy loam. Depth to bedrock ranges from 4 to 60 inches, but is predominantly less than 40 inches. Content of rock fragments ranges from 15 to 65 percent.

Surface runoff is rapid and the erosion hazard is high from water.

Rock outcrop consists of exposed shale or sandstone.

This unit is rangeland and is used for wildife habitat and limited livestock grazing.

APPENDIX D

Study Site Hydrology

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY
09243800 - FOIDEL CREEK NEAR OAK CREEK, CO.

PROCESS DATE 01/19/76
DISTRICT CODE 08

WATER QUALITY DATA, WATER YEAR OCTOBER 1975 TO SEPTEMBER 1976

DATE	TEMPERATURE (DEG C)	WEATHER (WMO CODE NUMBER)	STREAMFLOW (CFS)	STREAMFLOW, INSTANTANEOUS (CFS)	SPECIFIC CONDUCTANCE (MICROMHOS)	OXYGEN, DISSOLVED (MG/L)	PH (UNITS)	CARBON DIOXIDE DISSOLVED (MG/L AS CO2)	ALKALINITY (MG/L AS CACO3)	BICARBONATE (MG/L AS HCO3)	CARBONATE (MG/L AS CO3)	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N)
MAR 05...	.0	1	.42	.42	880	9.4	7.8	8.3	269	328	0	.11
APR 08...	4.0	0	--	.16	700	8.2	7.8	5.7	184	224	0	.03
MAY 07...	10.0	1	--	.71	800	5.5	7.8	8.3	267	326	0	.07
JUN 04...	13.0	1	--	.26	800	5.5	7.5	20	326	397	0	.00

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY
09243800 - FOIDEL CREEK NEAR OAK CREEK, CO.

PROCESS DATE 01/19/79
DISTRICT CODE 08

WATER QUALITY DATA, WATER YEAR OCTOBER 1975 TO SEPTEMBER 1976

DATE	PHOS-PHATE, ORTHO, DIS-SOLVED (MG/L AS PO4)	PHOS-PHORUS, ORTHO, DIS-SOLVED (MG/L AS P)	CARBON, ORGANIC TOTAL (MG/L AS C)	CARBON, ORGANIC DIS-SOLVED (MG/L AS C)	HARD-NESS (MG/L AS CACO3)	HARD-NESS, NONCAR-BONATE (MG/L CACO3)	CALCIUM DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)	SODIUM, DIS-SOLVED (MG/L AS NA)	SODIUM AD-SORP-TION RATIO	SODIUM PERCENT	POTAS-SIUM, DIS-SOLVED (MG/L AS K)
MAR												
05...	.09	.03	--	--	430	160	99	45	36	.8	15	3.8
APR												
08...	.06	.02	--	--	280	93	63	29	28	.7	18	3.5
MAY												
07...	.03	.01	--	--	360	95	84	37	25	.6	13	3.1
JUN												
04...	.31	.10	5.0	4.9	410	84	93	43	28	.6	13	2.8

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY
09243800 - FOIDEL CREEK NEAR OAK CREEK, CO.

PROCESS DATE 01/19/79
DISTRICT CODE 08

WATER QUALITY DATA, WATER YEAR OCTOBER 1975 TO SEPTEMBER 1976

DATE	CHLORIDE, DIS-SOLVED (MG/L AS CL)	SULFATE DIS-SOLVED (MG/L AS SO4)	FLUORIDE, DIS-SOLVED (MG/L AS F)	SILICA, DIS-SOLVED (MG/L AS SIO2)	ARSENIC DIS-SOLVED (UG/L AS AS)	BORON, DIS-SOLVED (UG/L AS B)	CADMIUM DIS-SOLVED (UG/L AS CD)	COPPER, DIS-SOLVED (UG/L AS CU)	IRON, DIS-SOLVED (UG/L AS FE)	LEAD, DIS-SOLVED (UG/L AS PB)	MANGANESE, DIS-SOLVED (UG/L AS MN)	NICKEL, DIS-SOLVED (UG/L AS NI)
MAR												
05...	6.0	210	.2	9.4	2	60	1	2	40	3	90	2
APR												
08...	4.2	140	.2	7.8	--	60	--	--	120	--	40	--
MAY												
07...	5.2	140	.3	7.4	--	50	--	--	40	--	90	--
JUN												
04...	4.6	46	.4	8.8	1	--	0	0	60	0	290	0

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY
09243800 - FOIDEL CREEK NEAR OAK CREEK, CO.

PROCESS DATE 01/19/79
DISTRICT CODE 08

WATER QUALITY DATA, WATER YEAR OCTOBER 1975 TO SEPTEMBER 1976

DATE	VANADIUM, DISSOLVED (UG/L AS V)	ZINC, DISSOLVED (UG/L AS ZN)	ANTIMONY, DISSOLVED (UG/L AS SB)	SELENIUM, DISSOLVED (UG/L AS SE)	ODOR, ATMOSPHERIC (SEVERITY)	SOLIDS, SUM OF CONSTITUENTS, DISSOLVED (MG/L)	SOLIDS, DISSOLVED (TONS PER DAY)	SOLIDS, DISSOLVED (TONS PER AC-FT)	MERCURY DISSOLVED (UG/L AS HG)	SEDIMENT, SUSPENDED (MG/L)	SEDIMENT DISCHARGE, SUSPENDED (T/DAY)
MAR											
05...	.6	10	0	0	0	572	.65	.78	.0	24	.03
APR											
08...	--	--	--	--	0	387	.17	.53	--	102	.04
MAY											
07...	--	--	--	--	0	463	.89	.63	--	54	.10
JUN											
04...	2.1	10	0	0	0	423	.30	.58	.0	48	.03

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY
09243800 - FOIDEL CREEK NEAR OAK CREEK, CO.

PROCESS DATE 01/19/79
DISTRICT CODE 08

WATER QUALITY DATA, WATER YEAR OCTOBER 1976 TO SEPTEMBER 1977

DATE	TEMPER- ATURE (DEG C)	WEATHER (WMO CODE NUMBER)	STREAM- FLOW (CFS)	STREAM- FLOW, INSTAN- TANEOUS (CFS)	SPE- CIFIC CON- DUCT- ANCE (MICRO- MHOS)	OXYGEN, DIS- SOLVED (MG/L)	PH (UNITS)	CARBON DIOXIDE DIS- SOLVED (MG/L AS CO2)	ALKA- LINITY (MG/L AS CACO3)	BICAR- BONATE (MG/L AS HCO3)	CAR- BONATE (MG/L AS CO3)
MAR											
18...	1.0	1	.10	.10	1050	4.0	7.2	39	320	380	0
APR											
14...	5.0	1	--	.08	850	6.5	7.2	31	250	310	0
MAY											
11...	5.0	1	--	.06	1000	3.0	7.1	51	330	400	0

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY
09243800 - FOIDEL CREEK NEAR OAK CREEK, CO.

PROCESS DATE 01/19/79
DISTRICT CODE 08

WATER QUALITY DATA, WATER YEAR OCTOBER 1976 TO SEPTEMBER 1977

DATE	NITRO- GEN, NO2+NO3 DIS- SOLVED (MG/L AS N)	PHOS- PHATE, ORTHO, DIS- SOLVED (MG/L AS PO4)	PHOS- PHORUS, ORTHO, DIS- SOLVED (MG/L AS P)	CARBON, ORGANIC TOTAL (MG/L AS C)	CARBON, ORGANIC DIS- SOLVED (MG/L AS C)	HARD- NESS (MG/L AS CACO3)	HARD- NESS, NONCAR- BONATE (MG/L CACO3)	CALCIUM DIS- SOLVED (MG/L AS CA)	MAGNE- SIUM, DIS- SOLVED (MG/L AS MG)	SODIUM, DIS- SOLVED (MG/L AS NA)	SODIUM AD- SORP- TION RATIO
MAR 18...	.24	.06	.02	11	8.6	550	230	130	54	33	.6
APR 14...	.04	.03	.01	--	--	410	160	98	41	30	.6
MAY 11...	.02	.37	.12	--	--	510	180	120	51	35	.7

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY
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PROCESS DATE 01/19/79
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WATER QUALITY DATA, WATER YEAR OCTOBER 1976 TO SEPTEMBER 1977

DATE	SODIUM PERCENT	POTASSIUM, DISSOLVED (MG/L AS K)	CHLORIDE, DISSOLVED (MG/L AS CL)	SULFATE DISSOLVED (MG/L AS SO4)	FLUORIDE, DISSOLVED (MG/L AS F)	SILICA, DISSOLVED (MG/L AS SIO2)	BORON, DISSOLVED (UG/L AS B)	CADMIUM DISSOLVED (UG/L AS CD)	COPPER, DISSOLVED (UG/L AS CU)	IRON, DISSOLVED (UG/L AS FE)	LEAD, DISSOLVED (UG/L AS PB)
MAR											
18...	12	4.4	6.5	300	.2	9.6	80	1	4	180	1
APR											
14...	13	3.9	6.9	210	.3	8.3	70	--	--	140	--
MAY											
11...	13	3.8	7.8	240	.2	9.4	100	--	--	100	--

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY
09243800 - FOIDEL CREEK NEAR OAK CREEK, CO.

PROCESS DATE 01/19/79
DISTRICT CODE 08

WATER QUALITY DATA, WATER YEAR OCTOBER 1976 TO SEPTEMBER 1977

DATE	MANGANESE, DISSOLVED (UG/L AS MN)	NICKEL, DISSOLVED (UG/L AS NI)	VANADIUM, DISSOLVED (UG/L AS V)	ZINC, DISSOLVED (UG/L AS ZN)	SELENIUM, DISSOLVED (UG/L AS SE)	ODOR, ATMOSPHERIC (SEVERITY)	SOLIDS, SUM OF CONSTITUENTS, DISSOLVED (MG/L)	SOLIDS, DISSOLVED (TONS PER DAY)	SOLIDS, DISSOLVED (TONS PER AC-FT)	SEDIMENT, SUSPENDED (MG/L)	SEDIMENT DISCHARGE, SUSPENDED (T/DAY)
MAR 18...	1100	13	.0	20	1	0	732	.20	1.00	50	.01
APR 14...	70	--	--	--	--	0	552	.12	.75	7	.00
MAY 11...	570	--	--	--	--	0	666	.11	.91	46	.01

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY
09243800 - FOIDEL CREEK NEAR OAK CREEK, CO.

PROCESS DATE 01/19/79
DISTRICT CODE 08

WATER QUALITY DATA, WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978

DATE	TEMPERATURE (DEG C)	STREAMFLOW, INSTANTANEOUS (CFS)	SPECIFIC CONDUCTANCE (MICROMHOS)	PH (UNITS)	CARBON DIOXIDE DISSOLVED (MG/L AS CO2)	ALKALINITY (MG/L AS CACO3)	BICARBONATE (MG/L AS HCO3)	CARBONATE (MG/L AS CO3)	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N)	PHOSPHATE, ORTHO, DISSOLVED (MG/L AS PO4)	PHOSPHORUS, ORTHO, DISSOLVED (MG/L AS P)
APR 18...	9.0	4.0	459	8.2	1.6	130	160	0	.46	.09	.03
MAY 30...	18.5	.85	600	8.2	2.8	230	280	0	.35	.03	.01
JUN 19...	17.0	.04	700	8.0	5.6	290	350	0	.01	.03	.01

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 01/19/79
09243800 - FOIDEL CREEK NEAR OAK CREEK, CO. DISTRICT CODE 08

WATER QUALITY DATA, WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978

DATE	CARBON, ORGANIC TOTAL (MG/L AS C)	CARBON, ORGANIC DIS-SOLVED (MG/L AS C)	HARD-NESS (MG/L AS CACO3)	HARD-NESS, NONCAR-BONATE (MG/L CACO3)	CALCIUM DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)	SODIUM, DIS-SOLVED (MG/L AS NA)	SODIUM AD-SORP-TION RATIO	SODIUM PERCENT	POTAS-SIUM, DIS-SOLVED (MG/L AS K)
APR 18...	--	--	220	87	48	24	15	.4	13	2.9
MAY 30...	--	--	310	84	71	33	17	.4	10	2.6
JUN 19...	9.2	11	370	86	85	39	21	.5	11	3.1

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY
09243800 - FOIDEL CREEK NEAR OAK CREEK, CO.

PROCESS DATE 01/19/79
DISTRICT CODE 08

WATER QUALITY DATA, WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978

DATE	CHLORIDE, DIS-SOLVED (MG/L AS CL)	SULFATE DIS-SOLVED (MG/L AS SO4)	FLUORIDE, DIS-SOLVED (MG/L AS F)	SILICA, DIS-SOLVED (MG/L AS SIO2)	ARSENIC DIS-SOLVED (UG/L AS AS)	BORON, DIS-SOLVED (UG/L AS B)	CADMIUM DIS-SOLVED (UG/L AS CD)	COPPER, DIS-SOLVED (UG/L AS CU)	IRON, DIS-SOLVED (UG/L AS FE)	LEAD, DIS-SOLVED (UG/L AS PB)
APR										
18...	3.9	120	.2	6.7	--	80	--	--	50	--
MAY										
30...	3.8	100	.3	9.4	--	70	--	--	280	--
JUN										
19...	3.4	100	.3	11	2	90	2	4	320	8

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UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY
09243800 - FOIDEL CREEK NEAR OAK CREEK, CO.

PROCESS DATE 01/19/79
DISTRICT CODE 08

WATER QUALITY DATA, WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978

DATE	MANGANESE, DISSOLVED (UG/L AS MN)	NICKEL, DISSOLVED (UG/L AS NI)	VANADIUM, DISSOLVED (UG/L AS V)	ZINC, DISSOLVED (UG/L AS ZN)	ANTIMONY, DISSOLVED (UG/L AS SB)	SELENIUM, DISSOLVED (UG/L AS SE)	SOLIDS, SUM OF CONSTITUENTS, DISSOLVED (MG/L)	SOLIDS, DISSOLVED (TONS PER DAY)	SOLIDS, DISSOLVED (TONS PER AC-FT)	MERCURY DISSOLVED (UG/L AS HG)
APR 18...	10	--	--	--	--	--	302	3.28	.41	--
MAY 30...	70	--	--	--	--	--	377	.37	.51	--
JUN 19...	230	0	.0	20	0	0	436	.05	.59	.0

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